CHAPTER 15

Process Liquid Storage Tanks

Steel containers are used for storing liquids in a process plant. Although many such vessels are found within the confines of a process unit, most vessels and tanks are located in areas commonly referred to as off sites or tank farms. The two most important factors governing these layouts are safety and economics. Any comprehensive design must consider local codes and regulations, client specifications, topography, adjacent process units, and neighboring commercial or residential property as well as maintenance, operation, and constructibility. This chapter discusses the most common types of storage vessels, plot plan arrangements, safety considerations, spill containment, pumping, and general piping layout.

CODES AND REGULATIONS

The plant layout designer should review codes and regulations of the National Fire Protection Association, the Occupational Safety and Health Act, and local jurisdictions.

National Fire Protection Association Codes

The latest issue of the following National Fire Protection Association (NFPA) codes should be reviewed before storage layout is begun:

- NFPA 11—Low-expansion foam and combined agent systems.
- NFPA 30—Flammable and combustible liquids code.
- NFPA 58—Storage and handling of liquefied petroleum gas.
- NFPA 59A—Production, storage, and handling of liquefied natural gas.
- NFPA 321—Basic classification of flammable and combustible liquids.

All NFPA codes are recommended as a basis for legal regulations. They are intended to reduce potential hazards to public safety, but compliance does not eliminate such hazards as those that occur when flammable and combustible liquids are stored in process facilities.

The Occupational Safety and Health Act

The main considerations in the layout of storage facilities that fall under Occupational Safety and Health Act (OSHA) regulations are personnel, access ladders, and stairways and catwalks.

Local Codes and Regulations

All documents concerning local codes and regulations should be reviewed before any off-site layout is begun.

TERMINOLOGY

The terminology used in text and illustrations is defined in the following sections.

Atmospheric tank This is a tank that operates at pressure levels ranging from atmospheric pressure to 0.5 psi.

Barrel A barrel is a standard unit of liquid volume in the petroleum industry that is 42 US gallons at 60° F.

Bullet This term describes a high-pressure horizontal storage vessel shaped like a bullet.

Cone-roof tank This is a low-pressure storage tank that has a fixed, cone-shaped roof.

Dike A dike is a barrier designed to contain liquid spills within a given area for safety reasons.

Distribution system This comprises equipment, piping mains, and services that carry and control gas supplies.

Diversion channel A diversion channel directs dangerous product spills away from primary diked areas to remote holding ponds.

Diversion dike This is a barrier designed to divert spills from other storage tanks; it uses natural terrain to direct liquids to a sump area.

Double-wall storage tank A double-wall storage tank has an inner wall to contain a liquid, an annulus space usually filled with insulation, and an outer wall for spill containment.

Fixed roof This is a low-pressure tank with a roof that is welded to the shell regardless of roof design or method of support.

Flame arrester In the event of lightning or another source of vapor ignition, a flame arrester in the vent line of a storage tank prevents flames from flashing to the vapor inside the tank.

Flame snuffer This is a device in a tank vent line that can be operated manually to snuff out a flame at the open end of the vent.

Floating-roof tank A floating-roof tank is designed to conserve vapor loss and minimize fire hazard.

Foam This is a solution with a density lower than that of oil and water. It is used to form a blanket over dangerous vapors and thereby reduce the risk of explosion.

Foot valve This valve is found at the bottom of a riser in a tank, where a submersible pump can be housed. During regular operation, the weight of the pump keeps the foot valve open. When the pump is removed, the spring-operated foot valve closes the riser pipe.

Heaters These are heat exchangers used inside large storage tanks. They heat viscous materials using steam, hot water, or other heating fluids.

Hortonsphere This spherical vessel is used to store liquids and gases at high pressure.

Intermediate holding tank This tank is used for temporarily storing a liquid until it reaches a specified state, at which time it is pumped downstream in a process.

Remote impounding basin Used for temporary storage of potentially dangerous liquids, a remote impounding basin is a containment area located away from a process or off-site facility.

Sediment This sludge accumulates in tanks and piping. It consists of dirt, wax, and mill scale and must be disposed of periodically.

Sleeper Sleepers are steel or concrete supports usually located within 18 in (450 mm) of grade for piping systems commonly found in off sites.

Sump This is the low point within an area used to collect liquids for removal.

Tank farm A location with many storage tanks is often called a tank farm.

TYPES OF TANKS

Storage tanks come in many shapes and sizes, according to the type of product to be stored, its potential for fire, and the amount to be held. This section discusses

EXHIBIT 15-1 Cone-Roof Tank

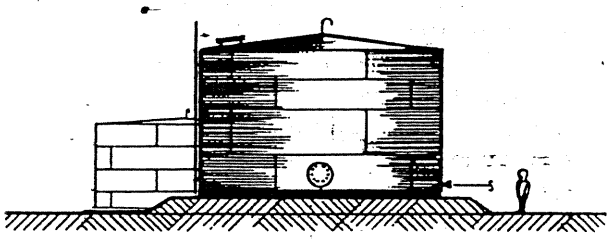


EXHIBIT 15-2 Floating-Roof Tank

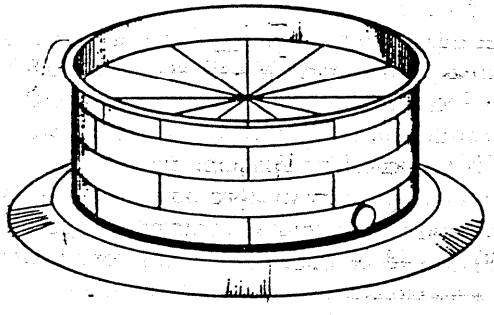


EXHIBIT 15-3 Low-Temperature Storage Tank

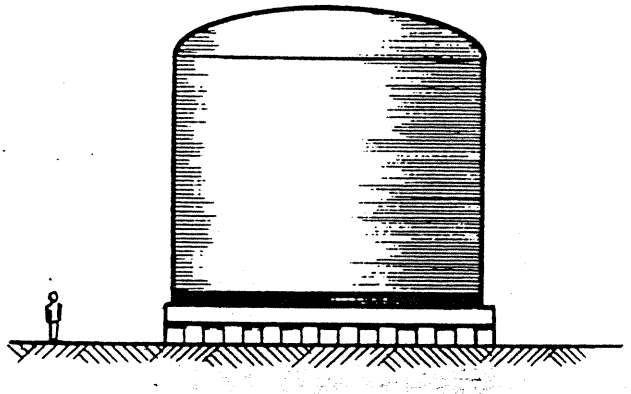
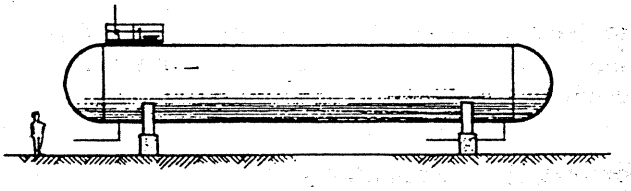


EXHIBIT 15-4 Horizontal Pressure Tank (Bullet)



the most common types of vessels found in most process facilities.

Cone-Roof Tank

This low-pressure tank (see Exhibit 15-1) is used for countless products, including petroleum, chemicals, petrochemicals, food products, and water. Another low-pressure storage vessel is the flat-roof tank.

Floating-Roof Tank

The roof of this tank (see Exhibit 15-2) rises and lowers with the stored contents, thereby reducing vapor loss and minimizing fire hazard. It is commonly found in oil refineries.

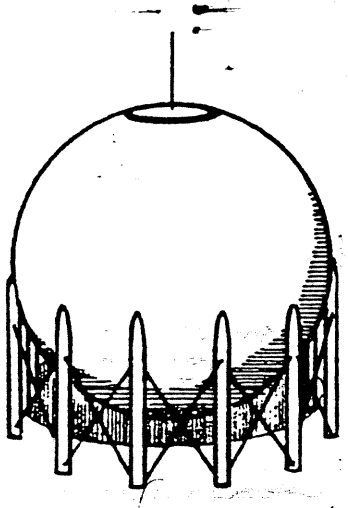
Low-Temperature Storage Tank

This tank (see Exhibit 15-3) stores liquefied gases at their boiling point. Products found in such tanks include ammonia (−28° F), propane (−43.7° F), and methane (−258° F).

Horizontal Pressure Tank (Bullet)

Bullet tanks (see Exhibit 15-4) are usually shop-fabricated vessels used to store products under high pres-

XHIBIT 15-5 Hortonsphere Pressure Tank



ire. The heads of these vessels are either elliptical or emispherical, the latter being used when higher ressures are required.

lortonsphere Pressure Tank

his tank (see Exhibit 15-5) is used to store large uantities of liquids and gases under pressure. Limited oad access to a plant site may make it more advanta- eous to erect a Hortonsphere in the field to store roducts under pressure.

PILL CONTAINMENT

ecause of the real risk of failure of storage tanks and rimary piping systems, means must be provided to ontain the resulting spills. Containment may be a sec- nd tank wall around the vessel holding the liquid or a ontinuous dike designed to hold all of the liquid tored in the largest tank. Dikes may be constructed of earth, steel, concrete, or solid masonry. They may be square, rectangular, circular, or irregular in shape, conforming to the natural terrain around them. Dikes may hold one or many tanks. NFPA 30 should be consulted for matters that concern the diking of flammable and combustible liquids.

One common design is to make the dike out of earth, as shown in Exhibit 15-6. Dike heights typically range from 3 ft to 6 ft (0.900 m to 1.800 m) above interior grade. The width of the dike at the top should be a minimum of 2 ft (0.600 m) unless it is designed to accommodate vehicular traffic. The dike slope must be consistent with the angle of repose of the material; otherwise, industry dike slopes are usually 1.5 : 1 (i.e., for every foot of dike height, the toe of the dike is 1.5 ft from its top edge).

Another dike design commonly found in restricted or tight areas is the concrete wall, shown in Exhibit 15-7. The location of storage tanks often must be within the battery limits of a process unit, and earthen dikes are not practical for this application.

Should it be necessary to store liquefied gas close to a population center, double containment (see Exhibit 15-8) should be considered. This containment method uses a circular concrete wall surrounded by a conventional earthen dike. It provides for complete spill containment should the primary dike fail.

Another method of containment for use with tall concrete dikes is shown in Exhibit 15-9. Adding an earthen berm on either side of the concrete wall allows the thickness of the concrete wall to be reduced.

Tanks are often located in sloped or hilly areas, where square or rectangular dikes would be impractical. The designer should consider using the natural terrain for a group of tanks, as shown in Exhibit 15-10. In addition, roadways and pumping facilities must be located to suit the terrain.

Exhibit 15-11 shows how natural terrain is used to direct spills from spheres of highly volatile liquid to flow to a single sump. This is done by installing a diversion dike between the spheres to reduce the risk

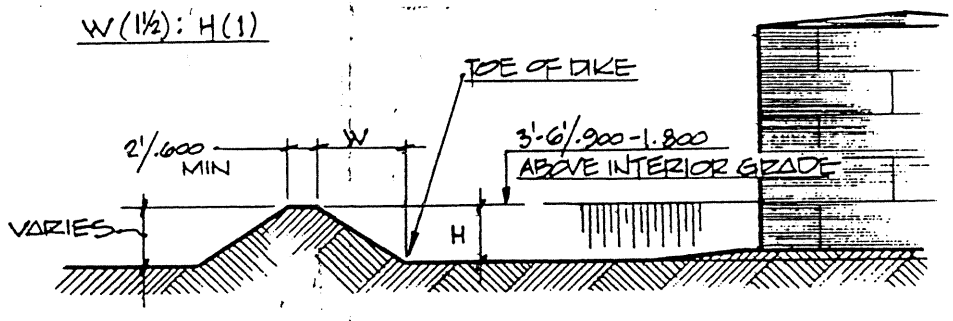


EXHIBIT 15-6
Earthen Dike

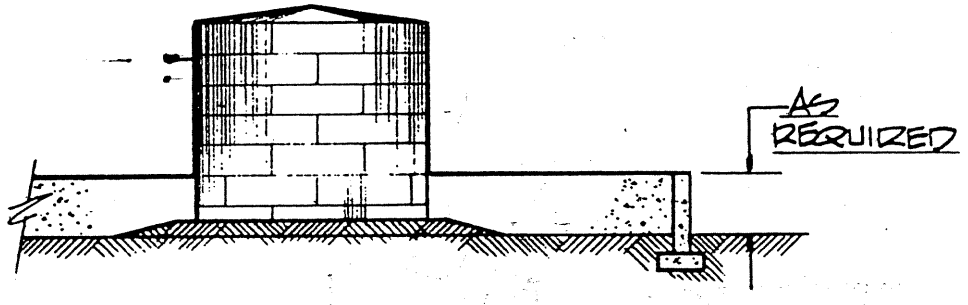


EXHIBIT 15-7
Concrete Dike

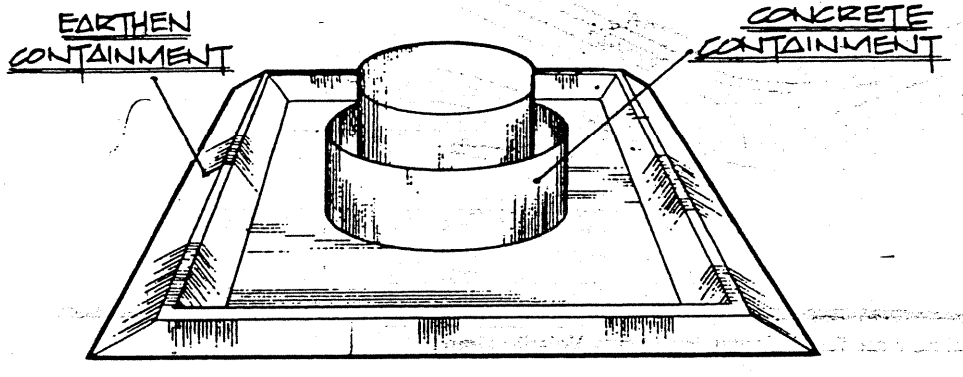


EXHIBIT 15-8
Double Containment Diking Method

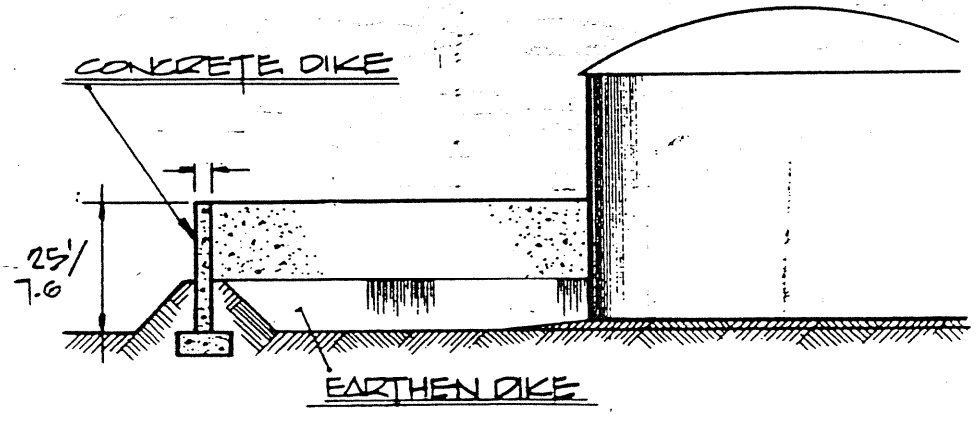


EXHIBIT 15-9
Earthen and Concrete Combination Dike

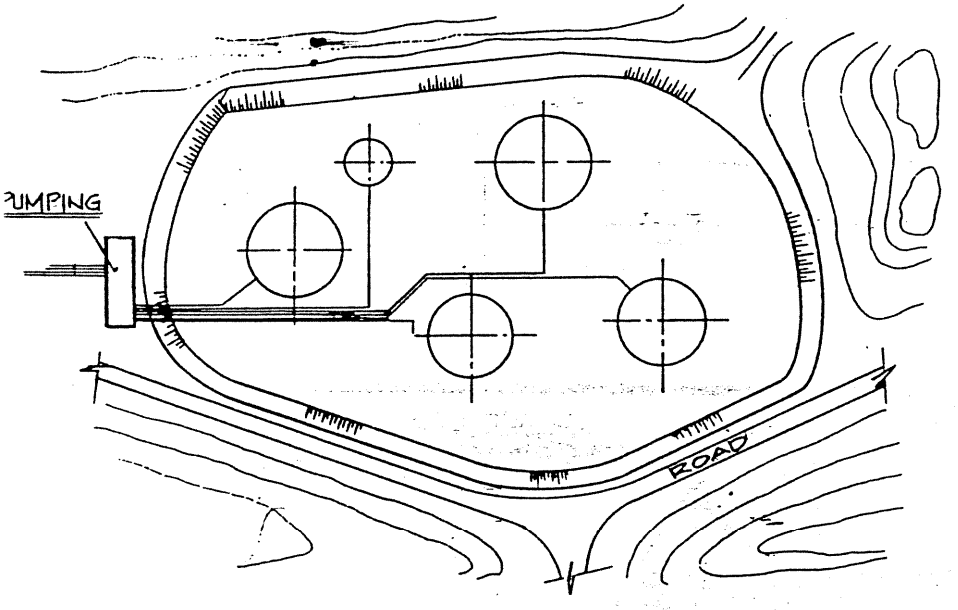
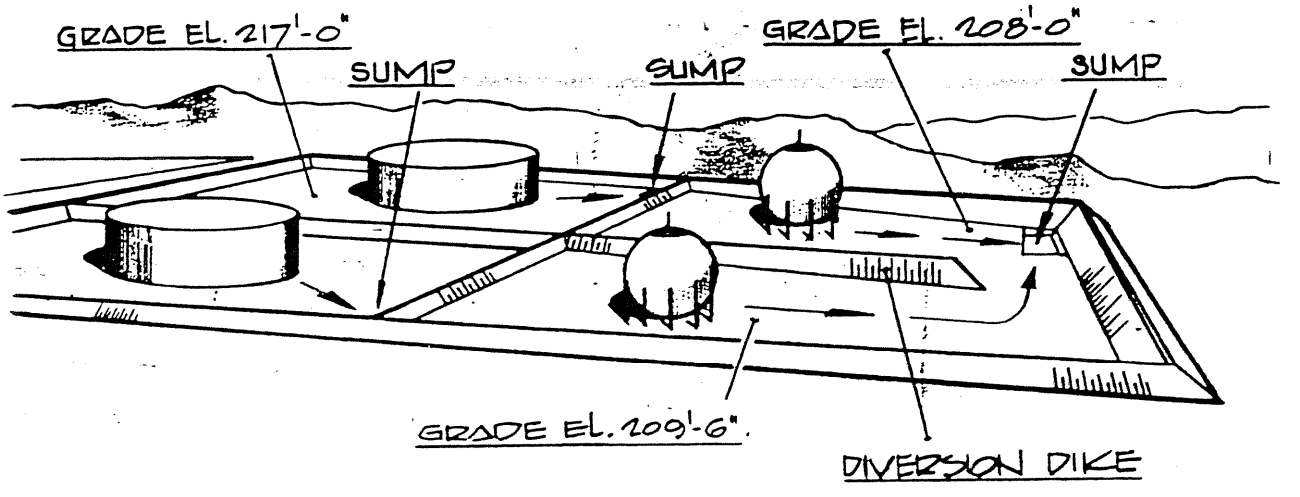


EXHIBIT 15-10
Natural Terrain Diking

EXHIBIT 15-11 Natural Terrain Diking with Tanks Containing Highly Volatile Liquids



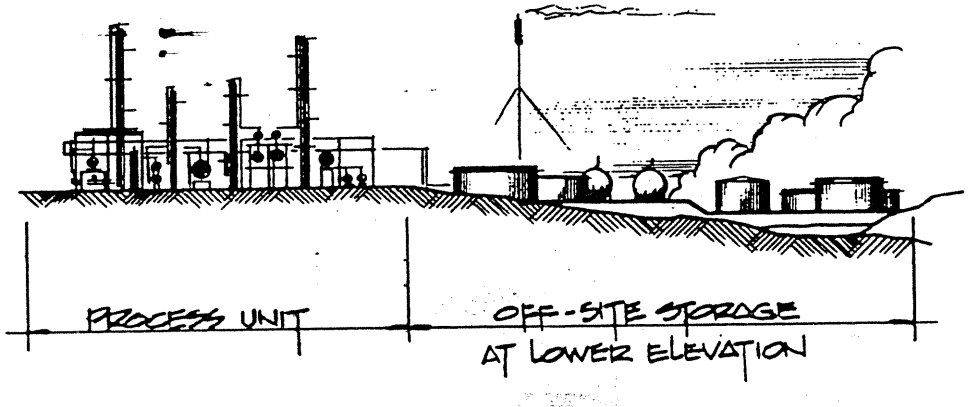


EXHIBIT 15-12
Plant Topography

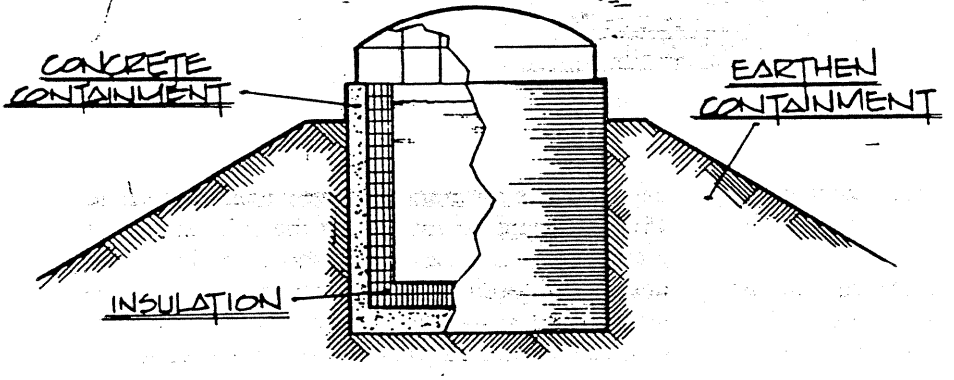


EXHIBIT 15-13
Earthen and Concrete Containment for Buried Low-Temperature Tank

of a fire spreading from one sphere to the other. As a result of the natural terrain, the spill is directed to its safest point within the dike.

When the overall plot plan for a process facility is developed, off-site storage should be set at a lower elevation than the process unit whenever possible. This approach (see Exhibit 15-12) provides an additional margin of safety in the event of a major rupture.

Containment of potentially dangerous liquefied natural gas spills is a significant concern to any operating facility. Therefore, extreme safety measures are employed, as shown in Exhibit 15-13. The inner tank is heavily insulated from the outer concrete containment and is buried in an earthen containment.

Developing a layout for buried storage tanks in an existing chemical plant often poses special problems. It may not be possible or practical to move existing underground obstructions in the area in which the tank must be located. One solution to this problem is to bury the tank above grade in a concrete contain-

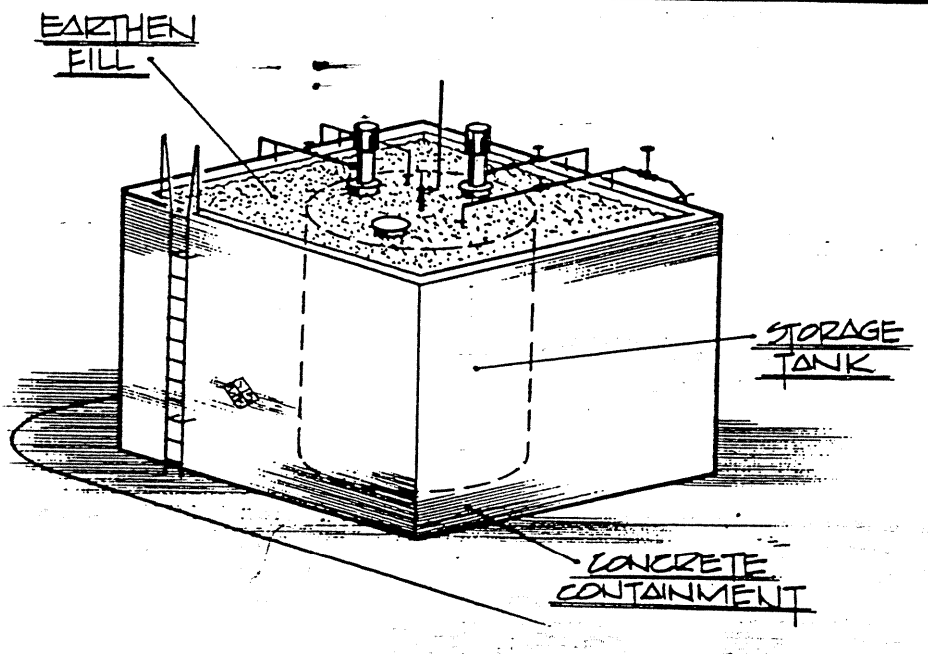


EXHIBIT 15-14
Tank Buried Above Grade

ient, as shown in Exhibit 15-14. Pumps, maintenance ccess, and all appurtenances must be installed in the oof of the tank.

Spills that pose a high risk to adjacent facilities must e diverted to a remote holding area. One method ould be to erect a concrete diversion canal (see Exibit 15-15). Drain valves that are located outside the iked area usually would be closed but would be pened in the event of a critical spill. Sump drain lines ischarge into the concrete diversion canal and flow ownward to a holding basin.

IKE ACCESS

onsideration must be given to providing vehicular id personnel access into diked areas. A typical arngement is shown in Exhibit 15-16. The maintenance vehicle ramp should have a maximum grade of 15%. It should be located on the side opposite the pump area. Personnel access should be by stairways designed according to OSHA standards. A single stairway located at the pump area provides access to a catwalk located on top of the dike. Two other stairways provide service access to the dikes, as shown in Exhibit 15-16.

When a layout of a tank farm must be developed at an existing facility, unmovable objects or structures may obstruct the dike area. Exhibit 15-17 shows how a dike may be designed to accommodate obstructions. Such designs are routine, but the spacing between the outside shell of the tank and the obstruction must meet NFPA or other governing regulations.

When initially trying to establish a tank farm layout, the designer should consult NFPA codes and local codes and regulations. Rules for spacing between

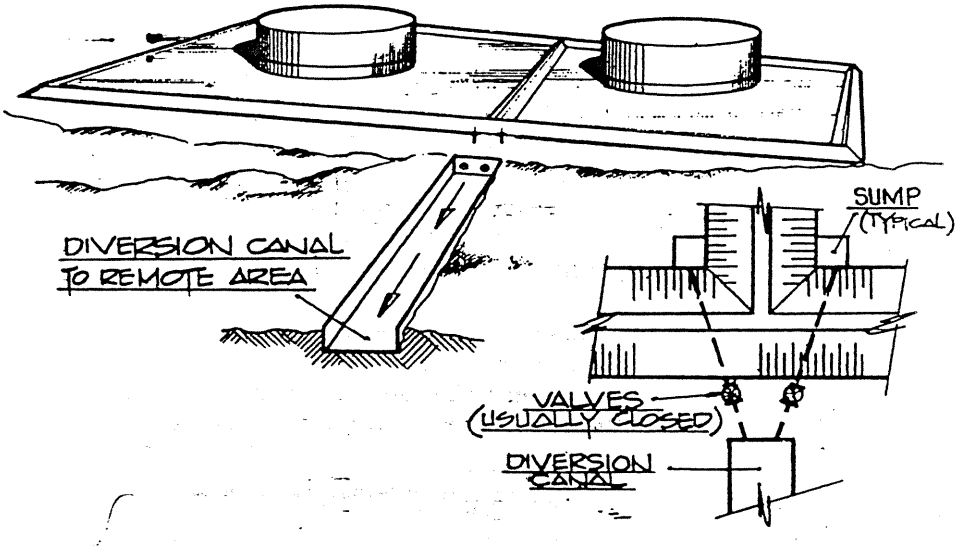


EXHIBIT 15-15
Concrete Diversion Canal

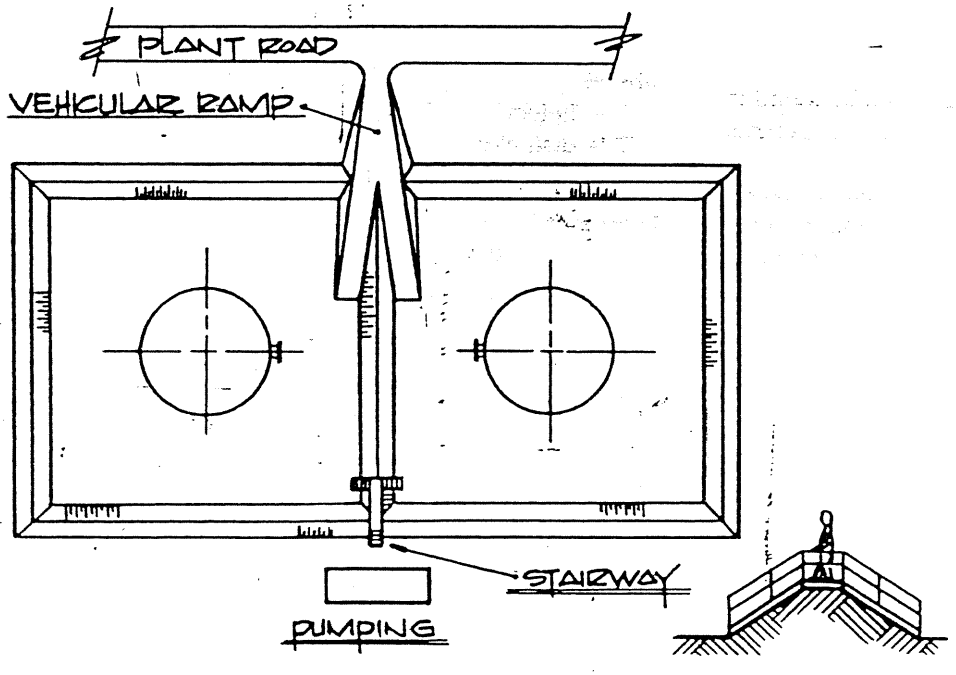
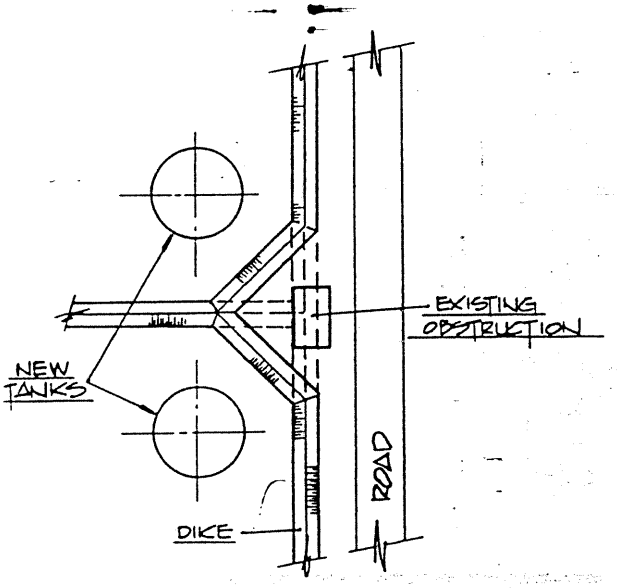


EXHIBIT 15-16
Vehicular and Personnel Access

XHIBIT 15-17 Building Dikes Around Obstructions



anks and all adjacent facilities usually can be found in he latest issue of the Industrial Risk Insurers "General Recommendation for Spacing" pamphlet.

The NFPA will indicate what the designer should consider when grouping several tanks within a single like or whether the tanks should be individually liked because of large capacities. There is no simple answer to this layout problem. Each plant site is unique, with different products, tank capacities, fire-prevention requirements, terrain, and adjacent commercial or residential property.

After the diking arrangement has been established, here are a few additional factors to plan for. The grade sloping away from the tanks to a sump must be determined; minor spills and rainwater may have to be pumped from the sump to a treating pond. Dike heights must also be established on the basis of inventories and available real estate.

SIZING TANKS AND DIKES

Development of optimum sizes for tanks and dikes comes through trial and error. Considerations include the availability of real estate, the possible use of standard-sized tanks for smaller capacities, and the nature of potential foundation design problems caused by early tank-size selections. The designer should refer to API 12F for standardized shop-fabricated tank sizes. Larger field-fabricated storage tanks must be sized to suit each site.

As an example of how to develop tank height and dike size, a 150,000-barrel (42 gallons per barrel), 150-foot-diameter tank is used. The first step is to convert the tank volume into cubic feet, as follows:

$$\frac{150{,}000 \times 42}{7.48} = 842{,}245 \text{ ft}^3 \text{ of liquid}$$

Tank height is calculated according to the following equation:

$$h = \frac{4V}{\pi D^2}$$

where:

h = height
D = diameter
V = volume (in cubic feet)

Therefore:

$$h = \frac{4 \times 842{,}245}{(3.1417)(150^2)}$$
$$= 47.66 \text{ ft or } 48 \text{ ft high}$$

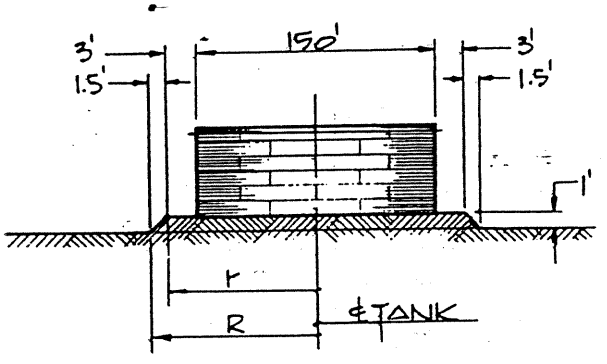
The volume of the tank berm is calculated as follows, using the data shown in Exhibit 15-18:

$$V = \frac{\pi h}{3}(r^2 + rR + R^2)$$

where:

r = top of berm radius (78 ft)
R = bottom of berm radius (79.5 ft)
h = berm height (1 foot)

EXHIBIT 15-18 Tank Berm Volume



Therefore:

$$V = \frac{3.1417 \times 1}{3}(6{,}084 + 6{,}201 + 6{,}320)$$
$$= 1.047 \times 18{,}605$$
$$= 19{,}479 \text{ ft}^3 \text{ of soil in the berm}$$

Calculation of the volume required in the diked area is as follows:

842,245 ft³ of stored liquid
− 19,479 ft³ of berm soil
822,766 ft³ dike area required

The chart in Exhibit 15-19 is used to find the dimensions of a square dike. For example, for a dike height of 6 ft, the designer first finds the 6-foot dike data line that corresponds to 822,766 ft³ and then reads directly left to the vertical axis to find the dike dimensions. In this example, a 380-square-foot dike would contain the liquid. *K* is the volume of liquid held within a dike that is constructed to a 1.5 : 1 slope.

The exhibit may also be used to calculate the dimensions of a rectangular dike. First, the designer locates the point on the vertical axis for the known length of one side of the rectangle—for example, 450 ft. Next, the designer reads to the right until the desired capacity (822,766 ft³) is found and then reads down vertically until the 6-foot dike data line is reached. Finally, the designer reads left to the vertical axis of the chart to find the missing dimension of the rectangle, 320 ft in this example.

Dikes containing multiple tanks are sized to hold the capacity of the largest tank. For the dimensions of dikes containing more than one tank, it is necessary not only to subtract the volume of each tank from the dike's capacity but to subtract the volume of the soil in each berm.

TANK DETAILS

After primary liquid-transfer line connections have been located, roof access ladders (or stairways) and side shell and roof maintenance access connections should be located. Exhibit 15-20 addresses these issues.

If tank heaters are employed, mobile maintenance equipment should be located in the most convenient area. Tank maintenance includes such activities as internal inspection, cleaning, and repairs to internals, roof supports, and level instruments. Setting entrances to stairway or ladder areas at grade is the most convenient choice for operations personnel. It should be noted that stairways are not recommended for tanks whose diameters are less than 15 ft 6 in (4.7 m).

For safety, handrails should be added along the tank roof edge on both sides of the ladder or stairway. Level instruments with internal floats are usually located in this area, as are roof maintenance access openings, which are convenient for inspections, repairs, and cleaning of instruments.

Two types of tank-shell maintenance access opening are shown in Exhibit 15-21. The standard, round opening is a minimum of 18 in (0.460 m) in diameter. The larger, oval-shaped, flat-bottom opening is more commonly used on large tanks or those that use inter-

EXHIBIT 15-19 Dike Volumes and Heights

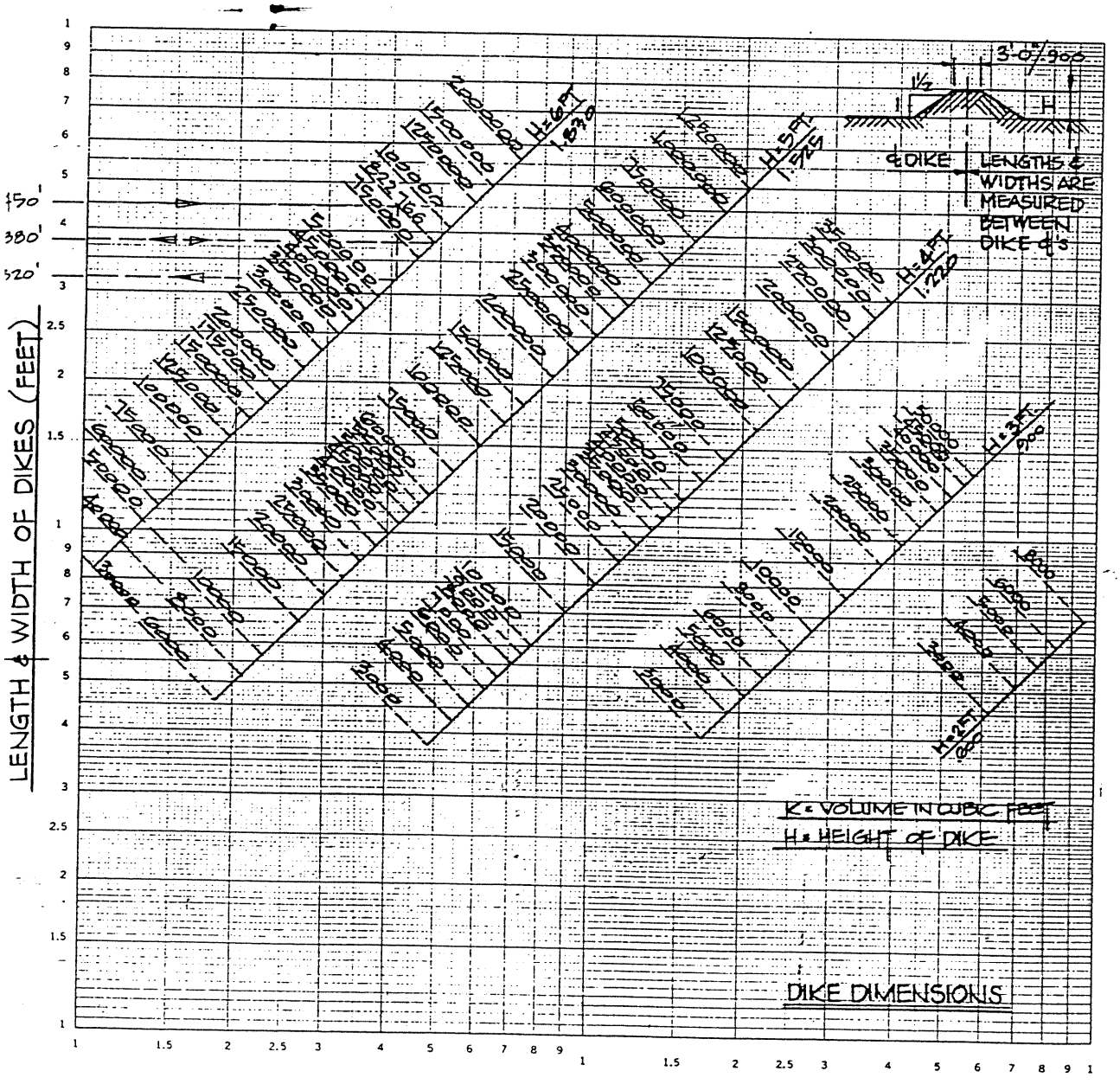
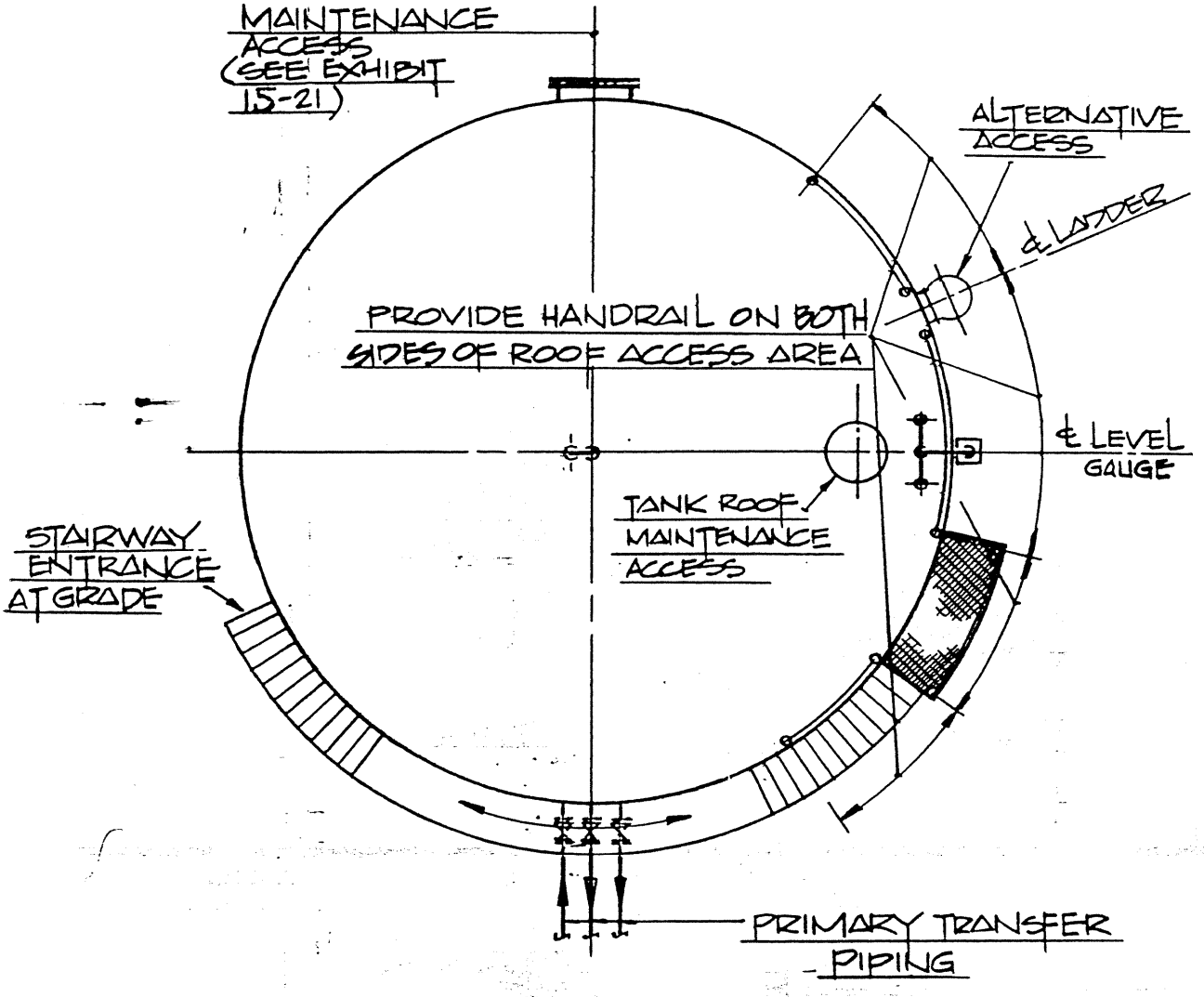
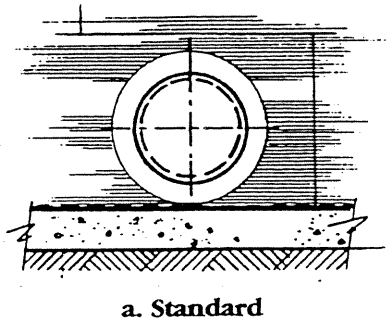
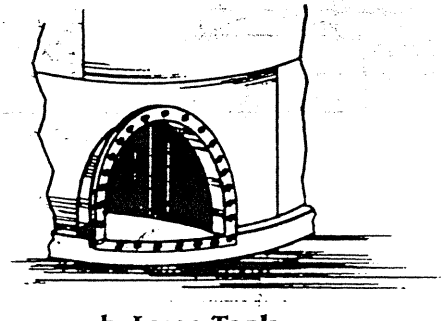


EXHIBIT 15-20 Tank Details


MAINTENANCE ACCESS (SEE EXHIBIT 15-21)
ALTERNATIVE ACCESS & LADDER
PROVIDE HANDRAIL ON BOTH SIDES OF ROOF ACCESS AREA
℄ LEVEL GAUGE
TANK ROOF MAINTENANCE ACCESS
STAIRWAY ENTRANCE AT GRADE
PRIMARY TRANSFER PIPING



a. Standard Maintenance Access



b. Large Tank Maintenance Access

EXHIBIT 15-21
Tank Maintenance Accesses

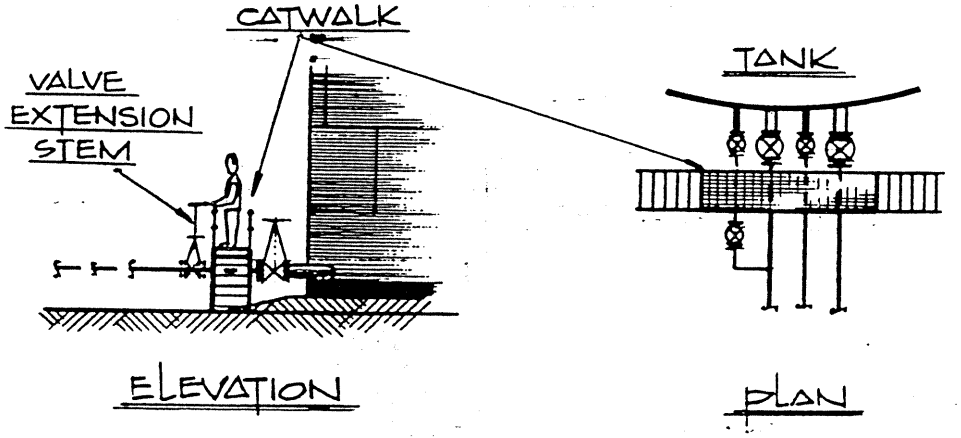


EXHIBIT 15-22
Valve Access Catwalks

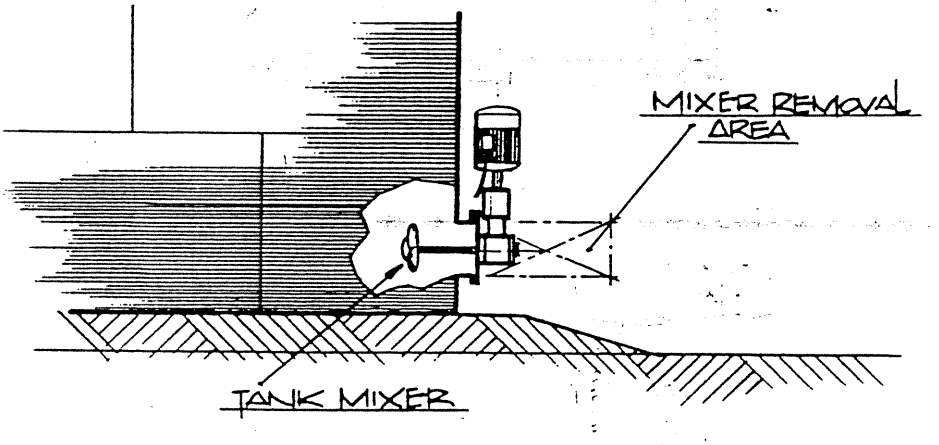


EXHIBIT 15-23
Tank Mixers

ial heaters. The layout designer must keep the area mmediately around access openings free of such obtructions as large pipe supports, piping, and light oles.

Valve access catwalks can be seen in Exhibit 15-22. t is of utmost importance to give operations personiel adequate access to primary tank valves. Consideration must be given to the elevation of all valve handwheels in relation to the catwalk. Adding extension stems to smaller valves will facilitate opening or closing such valves.

Tank mixers A tank mixer, shown in Exhibit 15-23, is another auxiliary piece of equipment found in tanks

EXHIBIT 15-24 Typical Tank Heaters

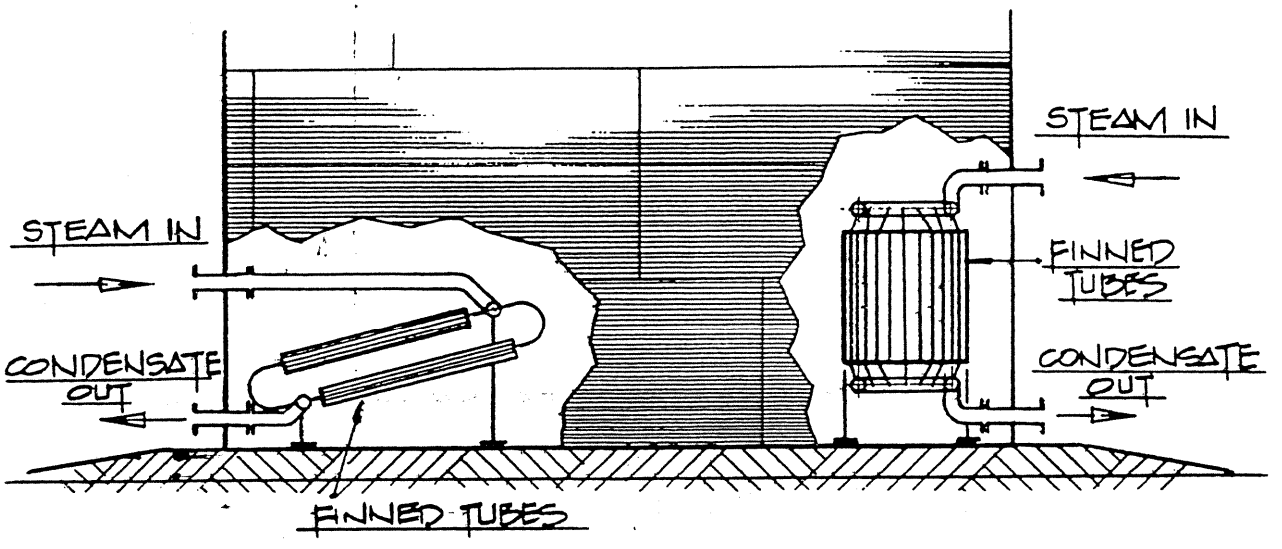
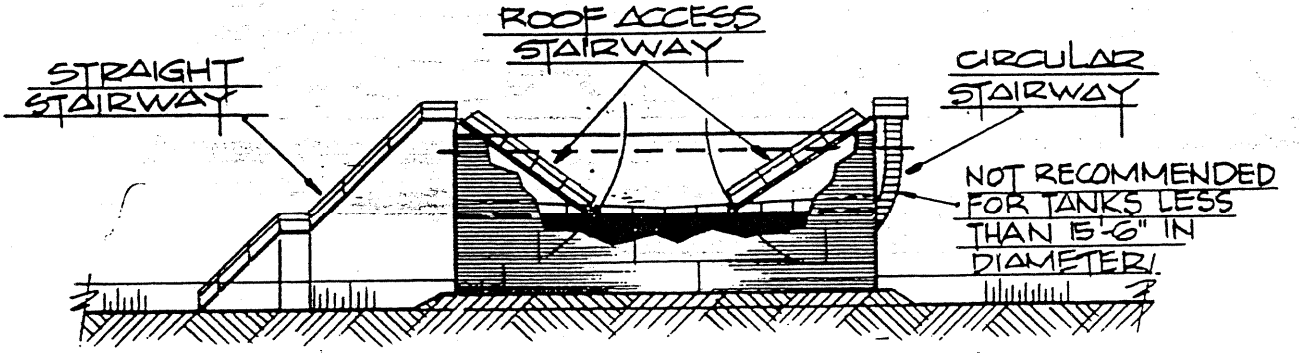


EXHIBIT 15-25 Floating-Roof Tank Access



with highly viscous fluids. Adequate area must be provided for removal of tank mixers.

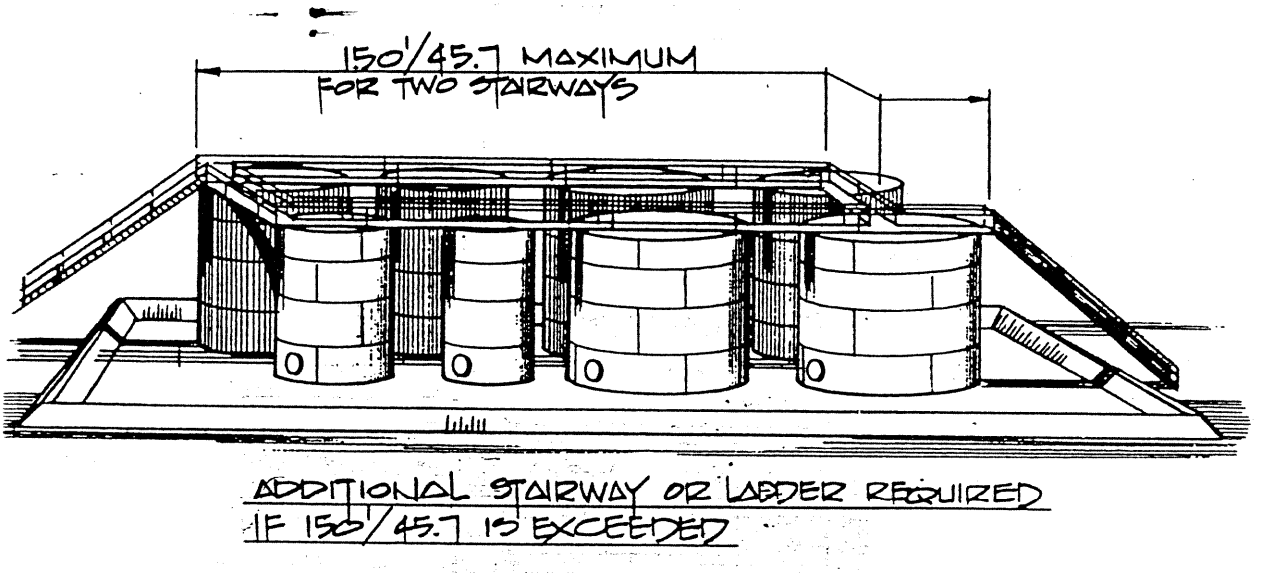
Tank heaters Tank heaters come in various sizes and shapes, as shown in Exhibit 15-24. Sufficient unobstructed space must be provided outside access openings to permit removal of heaters.

Floating-roof tank access Access to floating-roof tanks is shown in Exhibit 15-25. The straight stairway on the left of the diagram can be used for tanks of all diameters. Each stairway must have a landing outside the tank wall that allows adequate space for the stairway, provided by the tank vendor, down to the floating roof.

For storage areas with many small or medium-sized tanks, consideration should be given to designing interconnecting catwalks for operator convenience. The limiting factor is catwalk length, as shown in Exhibit 15-26. OSHA prohibits exceeding 150 ft (45.7 m) when only two means of egress are planned. Additional length can be accommodated by adding ladders or stairways.

Because of the need to avoid imposing heavy loads on the external tank or containment walls of most low-temperature tanks, consideration should be given to using access towers (see Exhibit 15-27). The rectangular tower on the left of the diagram supports all piping and a conventional stairway; the circular tower on the right carries all piping inside with a spiral stairway on the outside. Both provide access to the operations platform at the top of the tank. Economics and client

HIBIT 15-26 Interconnecting Catwalks



ference usually dictate design selection.

Another approach to accessing tank roofs is shown Exhibit 15-28. In this design, the interior dike elevan is lower than the outside grade, and all tank conctions are on the roof. Therefore, consideration ould be given to adding a catwalk over the dike allel to the piping. Plant personnel use a stairway the dike's outside wall to reach the catwalk, which inects to a ladder to the operations platform on top he tank.

NK SUPPORTS

ır common tank support designs are shown in ıibits 15-29 through 15-32. The civil engineer is ponsible for determining the most cost-effective ign, on the basis of available data about soil conditions. Layout designers should understand the fundamental nature of each design to optimize piping, stairway, and ladder locations without creating problems for construction or plant personnel.

A concrete ring wall is shown in Exhibit 15-29. The tank is supported by Class I compacted structural fill as well as a ring wall that is 12 in (0.300 m) thick.

Compacted granular fill support is shown in Exhibit 15-30. The top of the tank berm is 3 ft (0.900 m) wide, slightly sloped away from the tank wall, and coated with asphaltic concrete for weather protection.

A low-temperature tank foundation design is shown in Exhibit 15-31. This particular design employs a concrete slab supported by columns, providing an air space under the slab. This air space helps raise the temperature of the slab during a failure in the primary tank.

A more conventional low-temperature tank founda-

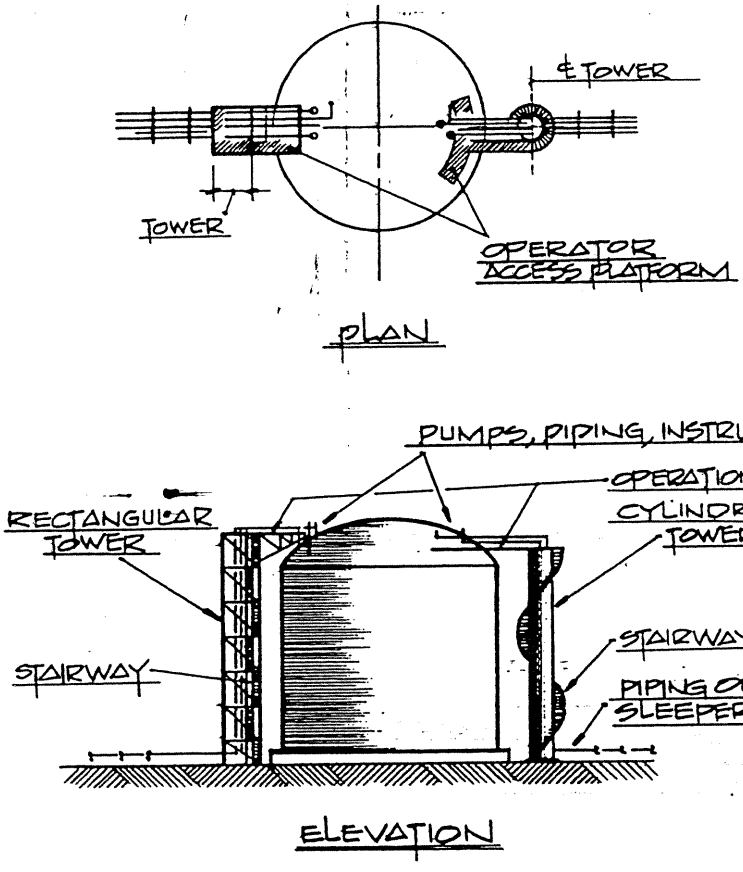


EXHIBIT 15-27
Piping and Personnel Access Tower

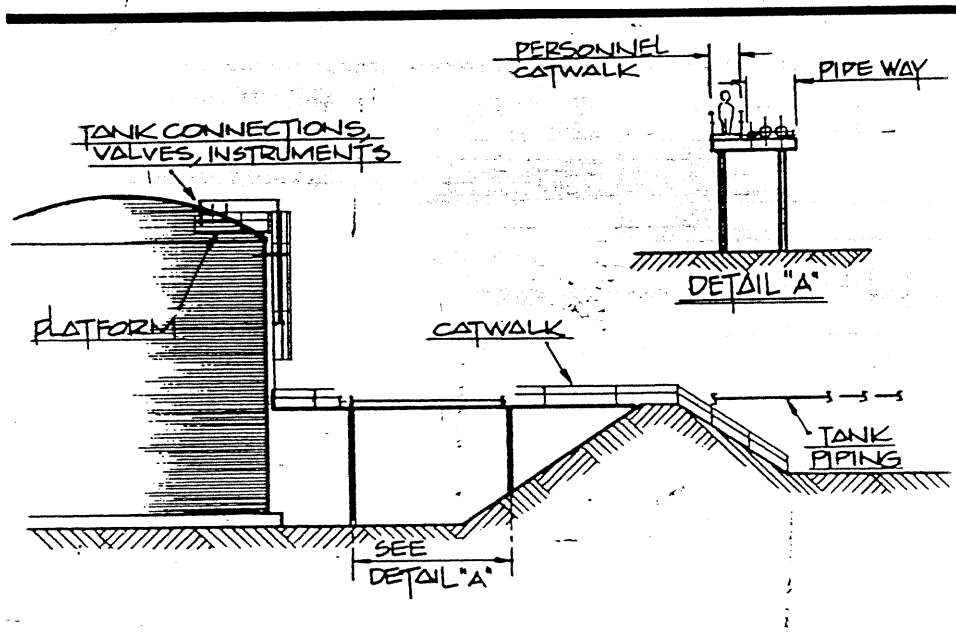


EXHIBIT 15-28
Elevated Pipe Way and Catwalk

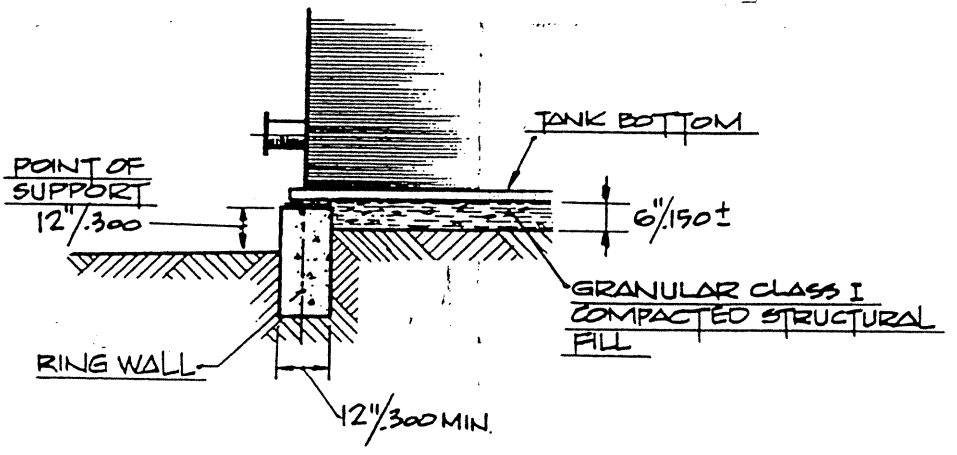


EXHIBIT 15-29
Ring Wall

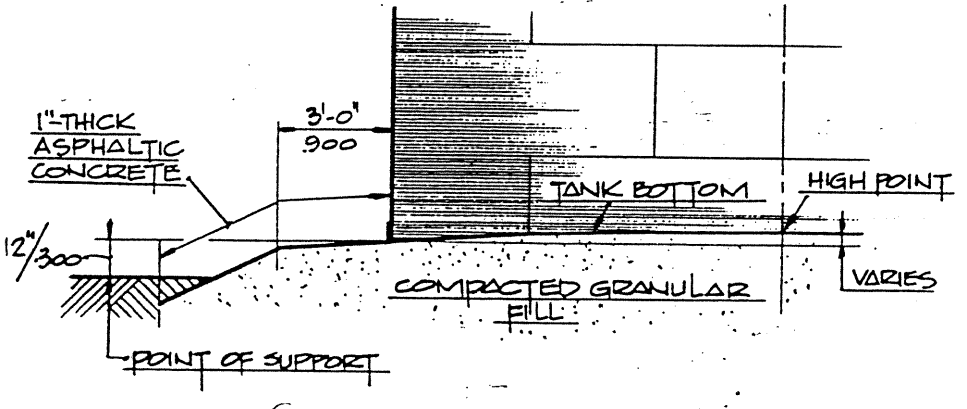


EXHIBIT 15-30
Compacted Fill Tank Pad

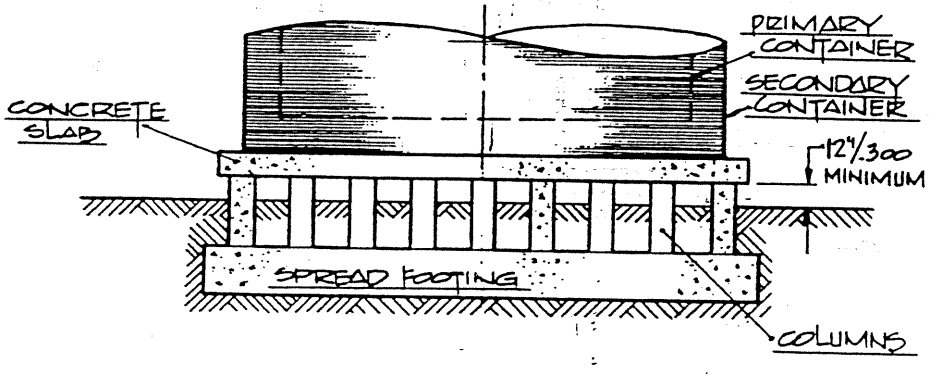


EXHIBIT 15-31
Low-Temperature Tank Foundation with Elevated Concrete Base

ion is shown in Exhibit 15-32. This design has an embedded heating element for use during possibly damaging spills. Consultation with civil engineers before any tank layout is undertaken is necessary to effectively use each design.

To establish the optimum location for pumps, consideration must be given to potential hazards and to client preference. Exhibit 15-33 shows the pump located in the earthen diked area, surrounded by a curbed wall that is 15 to 18 in (0.380 to 0.460 m) high. This design protects the pump from minor spills within the dike and enables the discharge piping to exit the dike over the wall, thereby eliminating the need for dike-penetration seals. Piping outside the

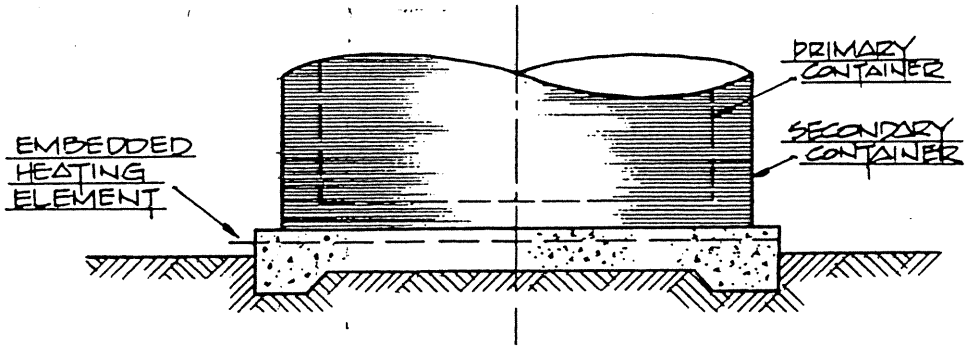


EXHIBIT 15-32
Low-Temperature Tank Foundation with Embedded Heating Element

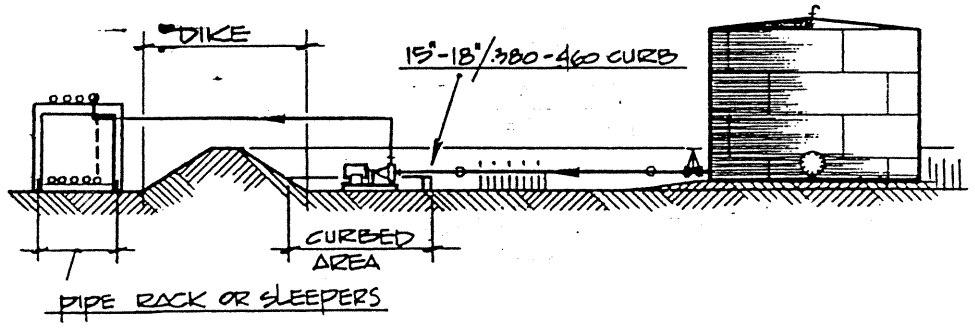


EXHIBIT 15-33
Pumps Inside Diked Area

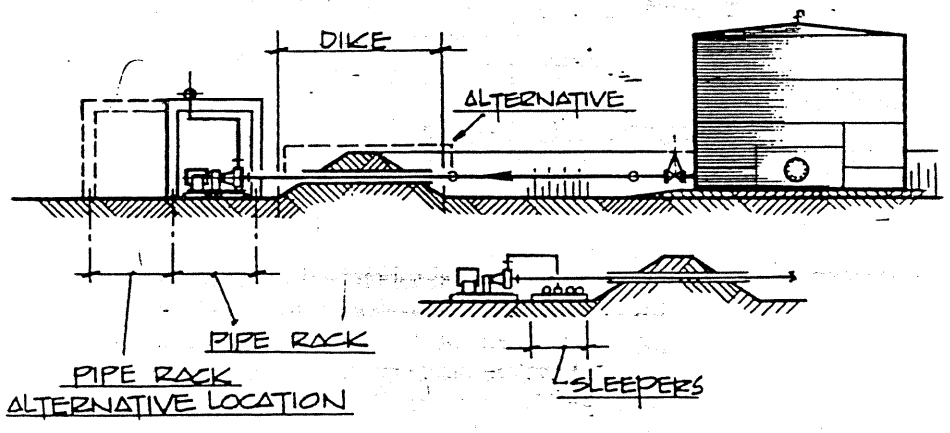


EXHIBIT 15-34
Pumps Outside Diked Area

dike may run on a pipe rack or sleepers.

Pumps located outside the dike are shown in Exhibit 15-34. Tank outlet piping can either penetrate the dike or pass over, as shown in this exhibit. The latter approach would usually be considered if the maximum dike height were 6 ft (1.83 m) and if the minimum liquid level in the tank would not cause damaging cavitation in the pump. The designer must carefully examine each layout before employing this design. The location of an elevated pipe rack or sleeper relative to the pumps should account for plant maintenance philosophy. Sleepers permit unobstructed pump access when located between the pump and the dike wall. Pumps located under pipe racks support discharge piping but limit access to pumps during maintenance. Prime consideration should be given to providing an ample maintenance area around and above pumps.

Locating pumps inside a concrete diked wall is common in many process plants. The approach shown in Exhibit 15-35 shows the pump block set at the same elevation as the dike. With this configuration, the

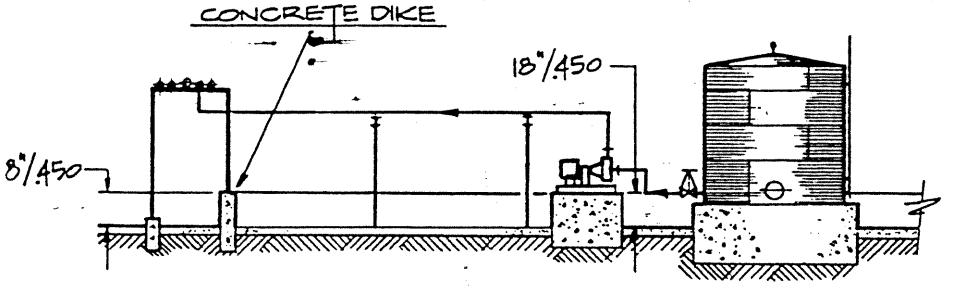


EXHIBIT 15-35
Pumps Inside Concrete Diked Area

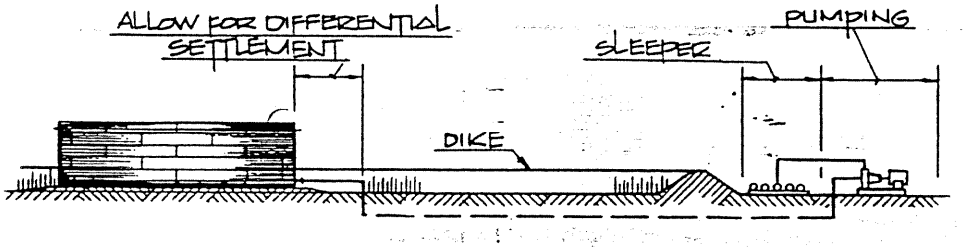
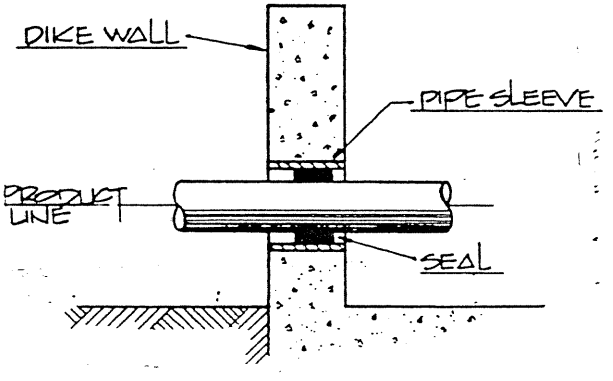


EXHIBIT 15-36
Buried Product-Transfer Piping

EXHIBIT 15-37 Dike-Penetration Seal



pump would not be submersed during a spill inside the dike. This configuration enables a close-coupled piping arrangement. Providing for differential settlement allows the discharge line to be run to the pipe rack over the dike wall. This approach should be approved by the client.

An alternative arrangement in routing product lines to pumps from very large tanks is shown in Exhibit 15-36. With the pumps located outside the earthen dike, the transfer piping is routed underground after allowances are made for differential settlement. This approach reduces potential damage to suction lines when extremely large inventories are involved.

Lines penetrating concrete dike walls may be secured against leakage by using commonly available seals. The design shown in Exhibit 15-37 permits minor axial movement. The seal shown in Exhibit 15-38 is used when an insulated line runs through a larger

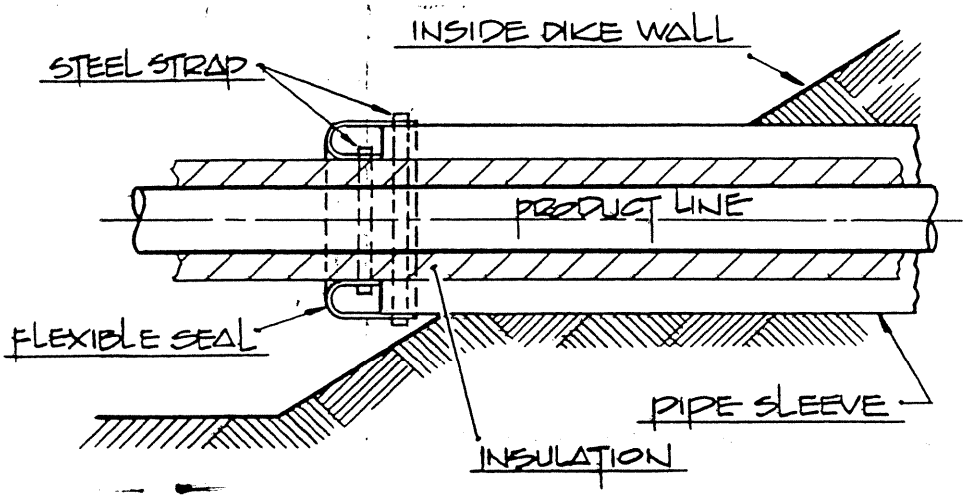


EXHIBIT 15-38
Flexible Dike Seal

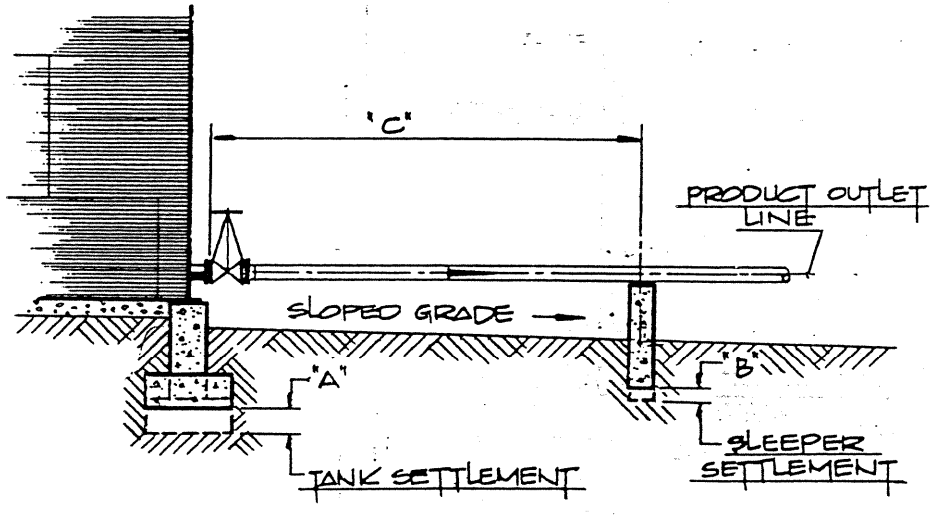


EXHIBIT 15-39
Differential Settlement

pipe sleeve that must be sealed on the inside of the dike. This design permits minor line movement. A stress or support engineer should be consulted when the designer is planning its application.

Differential settlement This concern must be addressed early in the layout of any process unit or tank farm. Exhibit 15-39 illustrates differential settlement. The foundation of any process facility will eventually settle or sink to some extent, depending on the weight it carries and the condition of the soil. To determine where pipes may be supported safely without imposing excessive stress on equipment nozzles, a civil engineer and soils experts must work together to determine how much the foundation is likely to settle. Subtracting sleeper settlement (distance B) from tank settlement (distance A) yields the differential settlement between the two. By figuring line size, wall thickness, and allowable stresses, distance C can be established. Differential settlement can also be caused by tilting of the tank, by out-of-plane settlement, or by dishing of the tank bottom (which is a result of greater settlement at the center of the tank than at the edge).

The optimum piping arrangement in a tank farm, as elsewhere in a process facility, is the most direct route between two points, allowing for normal line expansion and stresses. Exhibit 15-40 illustrates piping between tanks and pumps. Anchor points, or places where piping movement is restricted, must be established. Tank nozzles are one such anchor point. The second anchor point may be the pump nozzle if line growth is permitted through the dike, or it may be

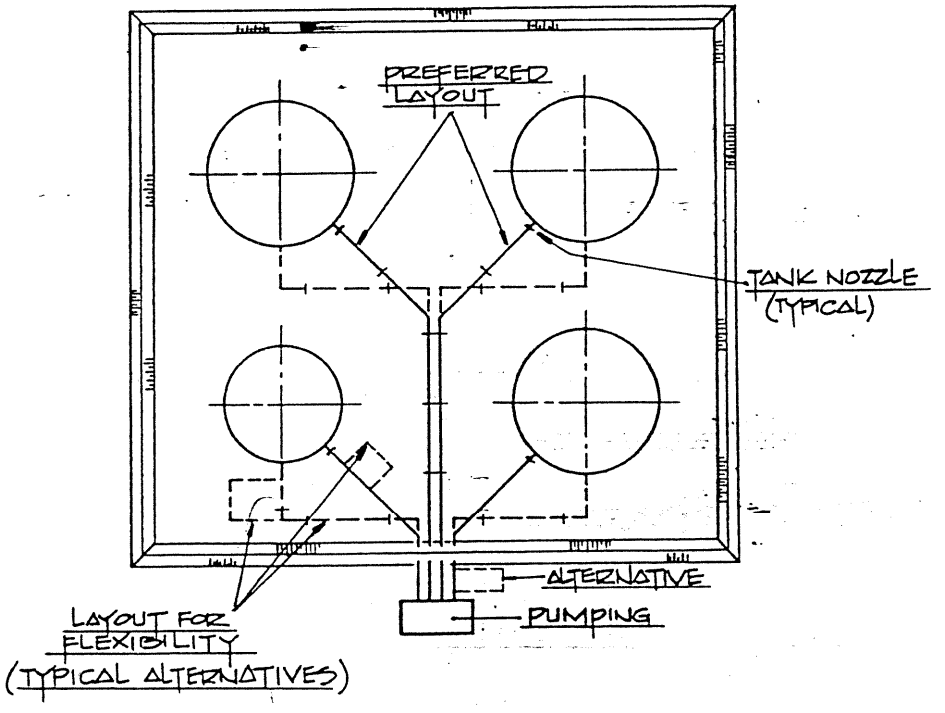


EXHIBIT 15-40
Alternative Piping Layouts

anywhere along the piping within the dike or at the point of dike penetration. To minimize the potential for tank spills, expansion joints should not be used.

Exhibit 15-41 shows how to accommodate line expansion between tank nozzles and a manifold header. Expansion loops may be added at the sleeper level, as shown for lines A and B. Expansion may also be allowed for by running line C directly over the header, perpendicular to the portion of the line causing the expansion.

Exhibit 15-42 illustrates a cross section of piping, pumps, dikes, and a primary pipe way that is typical of what might be found in a tank farm. Because the primary pipe way is located to the left of the roadway, pump-discharge lines across the road must be routed to the headers in one of two ways: by burying them under the road, making allowances for vehicular loads imposed on the pipe, or by placing them over the road on a pipe bridge. Client preference should be considered in this design. Adequate access to pumps on the side of the pipe way opposite the road must also be provided.

A bullet-tank piping layout is shown in Exhibit 15-43. Tanks are set at the lowest possible elevation to satisfy pump head requirements. A catwalk is located across all four tanks to provide sufficient access to operating valves and instruments. Liquid outlet piping to the pumps should allow for differential settlement and line flexibility. A fire water spray protection system for bullets is shown in Exhibit 13-36.

A typical piping arrangement for a high-pressure Hortonsphere is shown in Exhibit 15-44. Layout factors

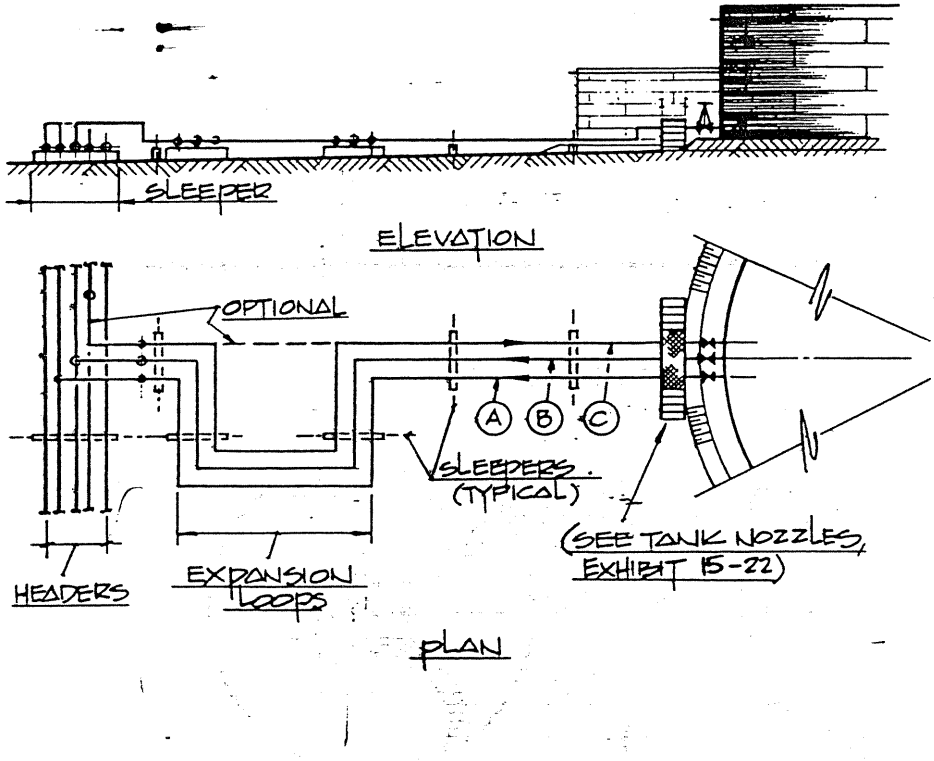
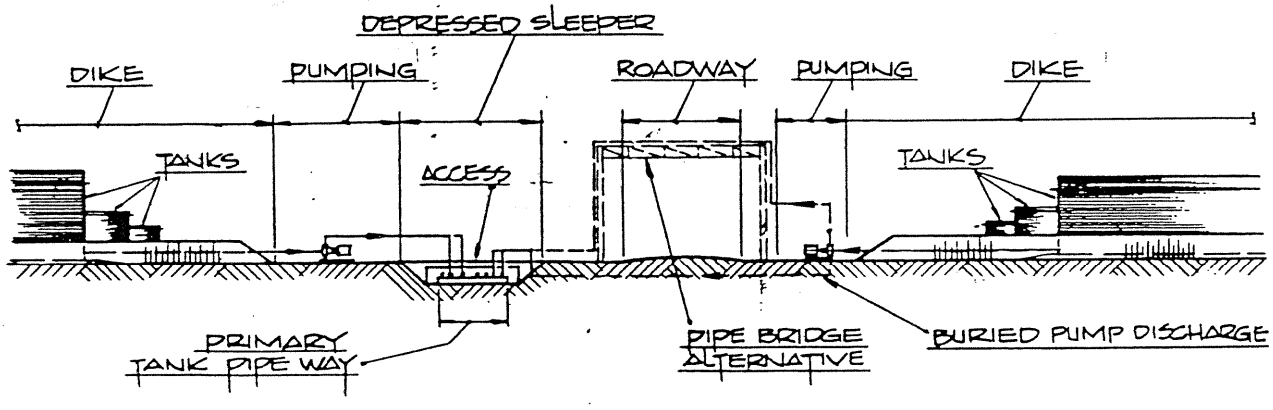


EXHIBIT 15-41
Tank Piping Layout

EXHIBIT 15-42 Cross Section of Pipe Way and Pumping



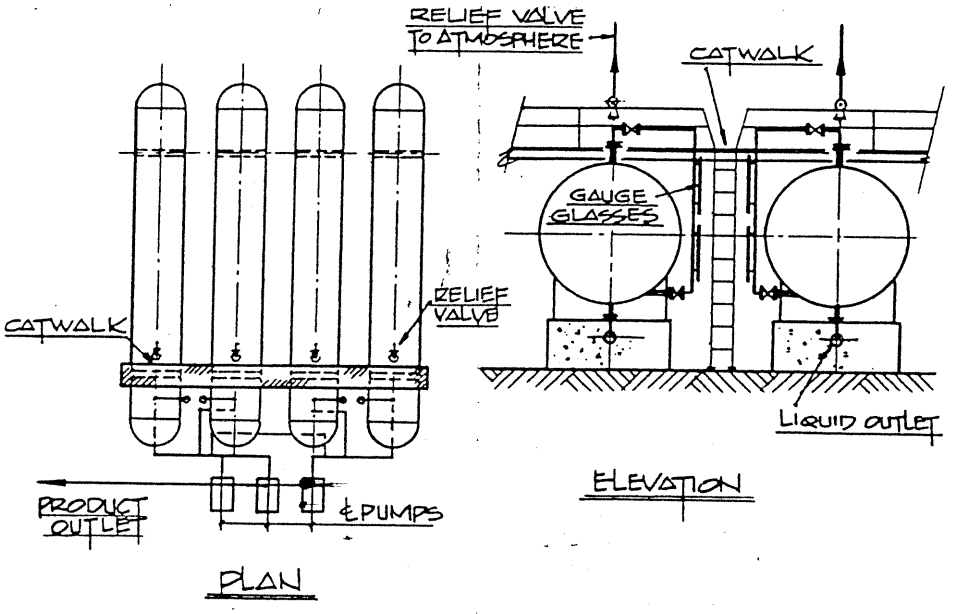
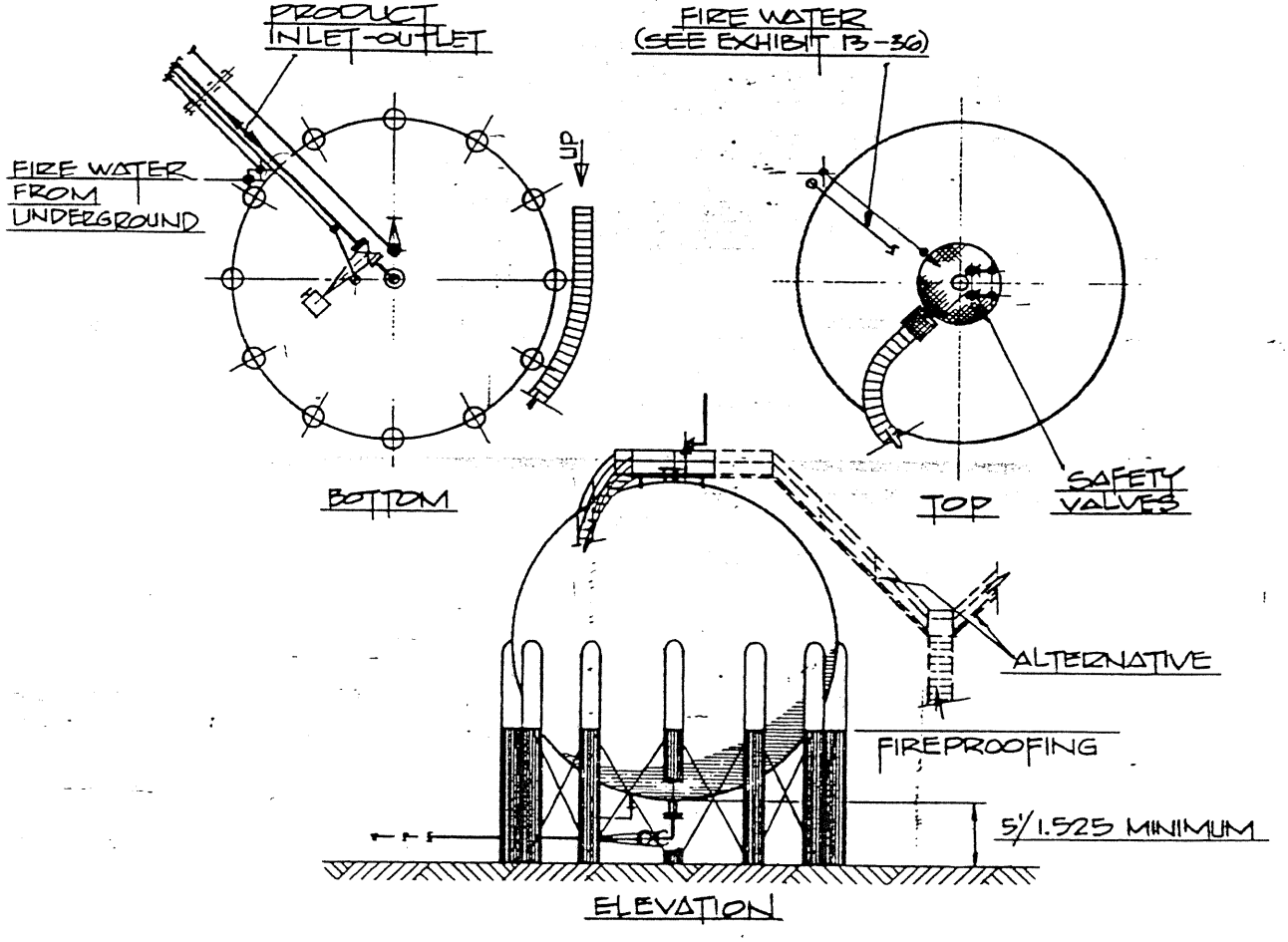


EXHIBIT 15-43
Bullet-Tank Piping Layout

EXHIBIT 15-44 Hortonsphere Piping Layout



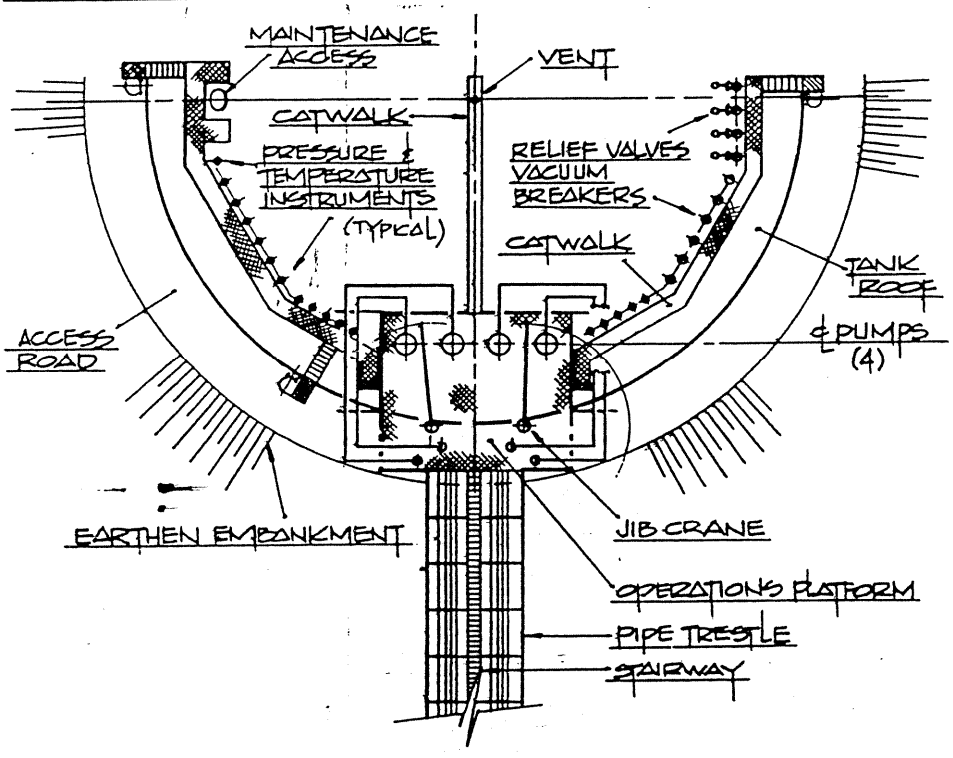


EXHIBIT 15-45
Liquefied Natural Gas Tank Layout

for spheres include:

- Tank elevation should be kept low but not less than 5 ft (1.525 m) above grade.
- Ideally, each tank should have its own stairway—Exhibit 15-44 shows an acceptable alternative arrangement.
- Valves should be installed as close as possible to all nozzles.

Typical layouts of liquefied natural gas tanks in an earthen embankment are shown in Exhibits 15-45 and 15-46. Features of this arrangement include:

- The secondary containment is a steel-lined concrete structure.
- There is heavy cryogenic insulation between the primary and secondary containers.
- The earthen embankment provides an acceptable margin of safety in the event of tank failure.
- Submersible pumps are located at the bottom of the pump shaft.
- The roof is steel domed.
- The operations platform, piping, and jib crane are supported from the concrete containment wall.

The stairway on the pipe trestle provides access to the operations platform and tank roof. Additional ladders are provided from the circular access road around the tank to the catwalk. This platform provides access to relief valves, vacuum breakers, maintenance access openings, and instruments.

If an above-grade, more conventional layout is preferred for liquefied natural gas tanks, a layout similar to that shown in Exhibit 15-47 may be used. NPSH requirements usually necessitate locating the pumps in a pit when the tank is above grade. A submersible pump and its motor are located within a containment vessel and supported on lugs. An adequate clear area directly over the pumps must be maintained to allow pump removal for maintenance. Motor-operated header valves are located at grade and made accessible by platforms. Individual suction and discharge valves are located near the nozzle connections in the pit. Safety requires that a water-deluge fire-fighting system be included in this layout as well as a sump and sump pump to remove unwanted water.

When high-pressure bullet tanks are located close to a process unit, a protection berm is often used (see Exhibit 15-48). Berm length is slightly longer than the width of the tank area, and the berm height is roughly equal to the height of the tanks. These berms offer some protection in the event of an explosion.

Although foam fire-fighting systems are often supplied by companies specializing in fire protection, a

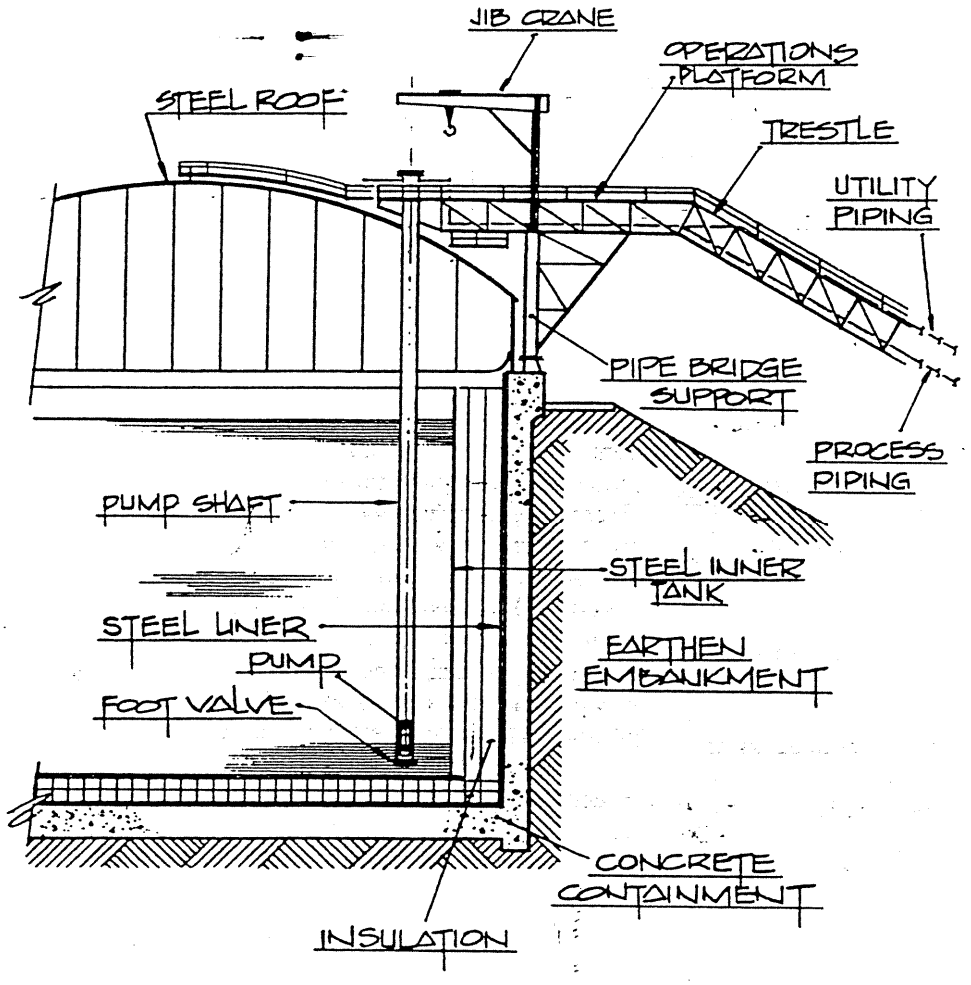


EXHIBIT 15-46
Liquefied Natural Gas Tank

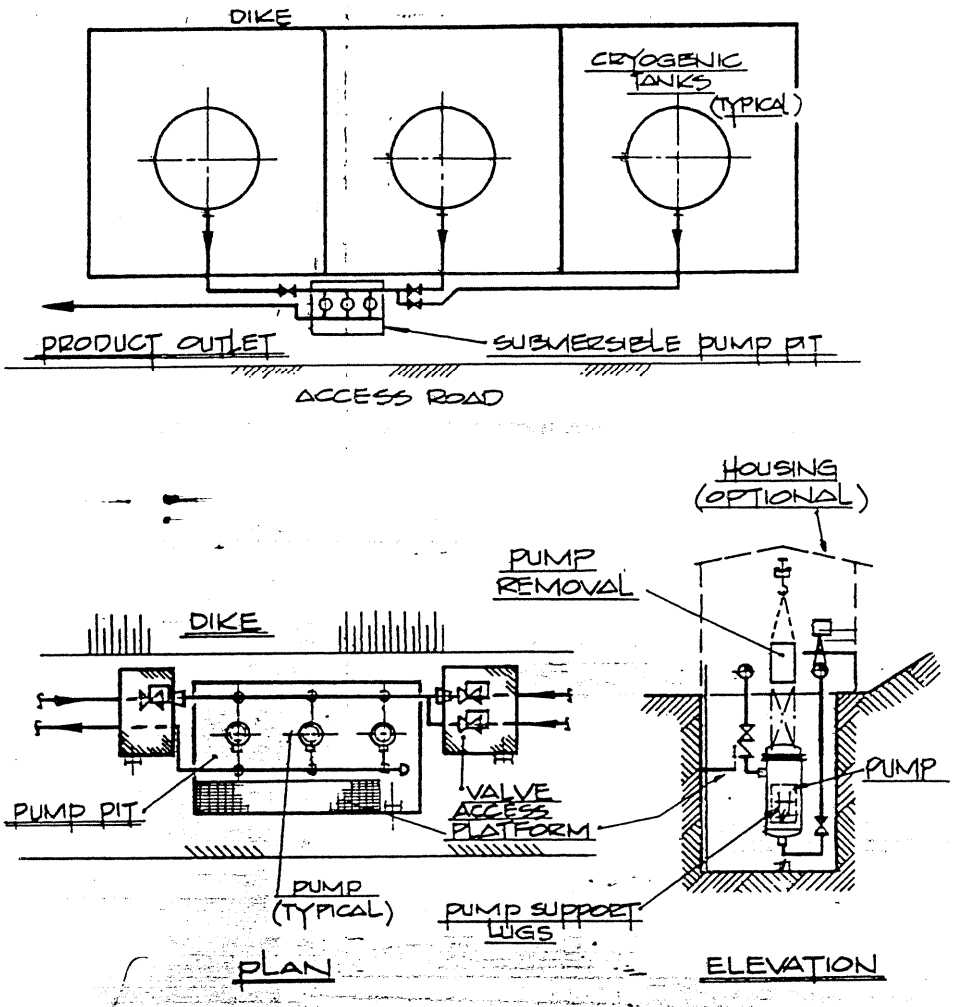


EXHIBIT 15-47
Above-Grade Liquefied Natural Gas Tank Layout

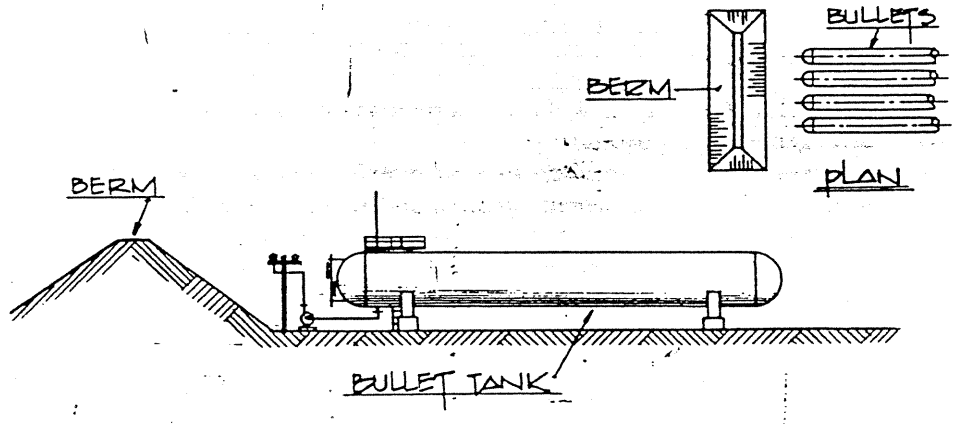
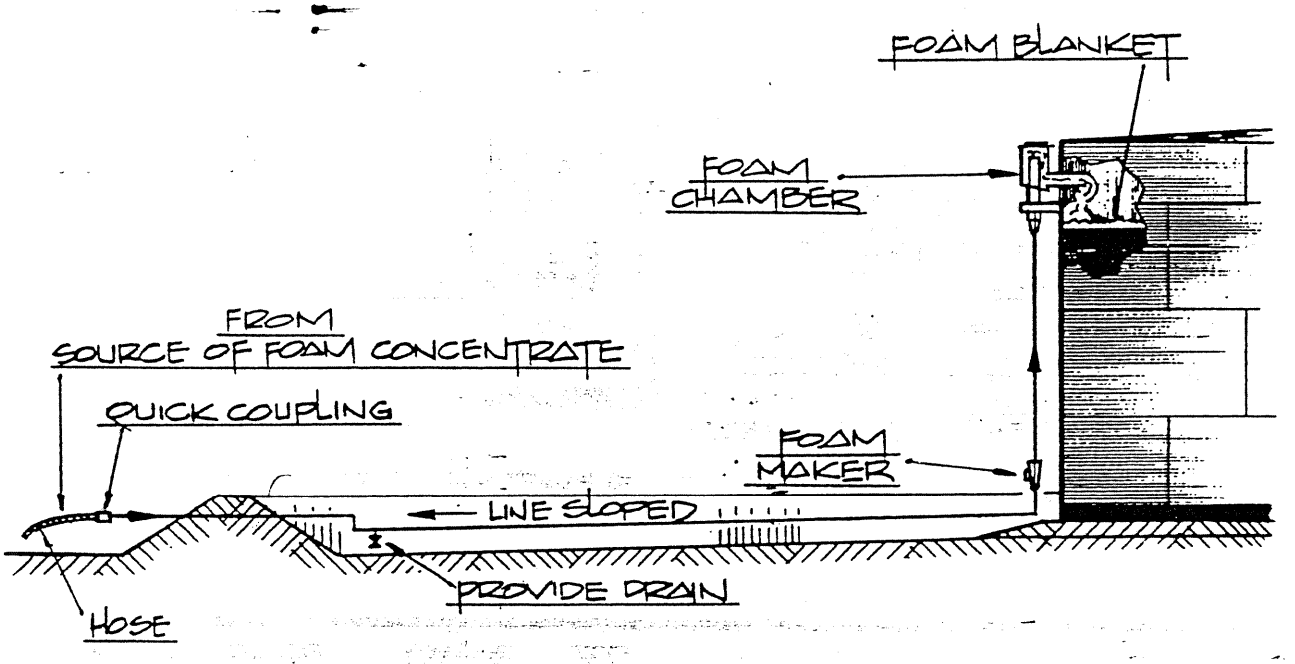


EXHIBIT 15-48
Protection Berm

EXHIBIT 15-49 Foam Injection into Tanks



basic understanding of such systems is beneficial to a layout specialist. Exhibit 15-49 shows an arrangement in which foam concentrate is pumped with water from a truck to a storage tank. The piping usually has quick-connect coupling located outside the dike. The line is routed to the tank wall. A foam maker—which essentially consists of a pressure gauge, an air strainer, and a check valve—is located in the vertical riser. The foam solution enters a foam chamber located at the edge of the tank roof and then discharges across the top of the liquid in the tank.

Another way of injecting foam into a tank is shown in Exhibit 15-50. Foam concentrate from a truck or tank is supplied to a foam maker located outside the dike wall. The foam may be injected into the regular product transfer piping or routed directly to the storage tank through a permanent line especially for that purpose.

An alternative to mobile fire-fighting equipment, permanent hydrants and monitors may be used for fighting fires in storage tank areas. Local codes and regulations as well as the latest issue of NFPA must be consulted to establish the appropriate coverage of water for a given layout. Exhibit 15-51 shows how fire hydrants and monitors may be arranged in a tank farm. The fire water piping around this area must come from two supply sources should any part of the system fail.

Exhibit 15-52 illustrates an effective overall layout of a process and off-site plot plan. The administration area is immediately inside the plant's main entrance, as are maintenance and fire-fighting equipment. Pro-

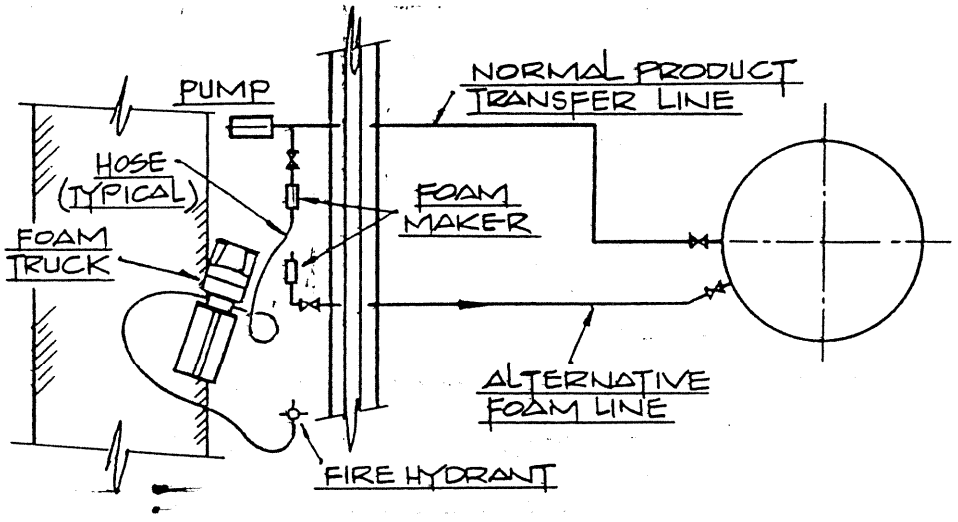


EXHIBIT 15-50
Semiportable Foam System

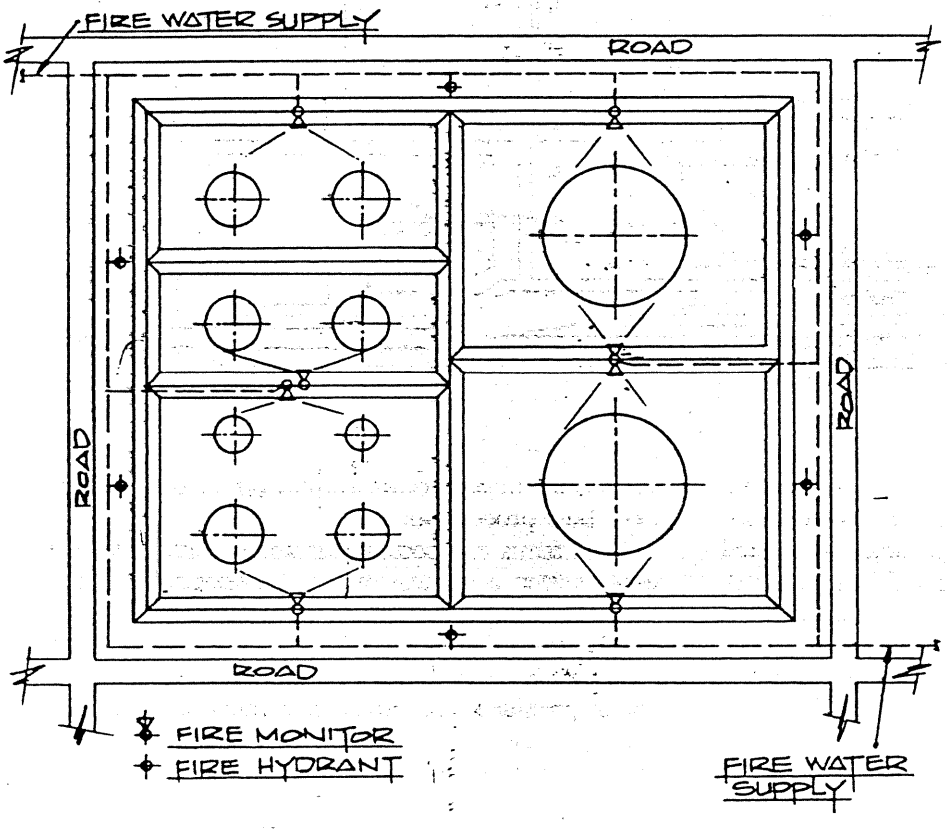
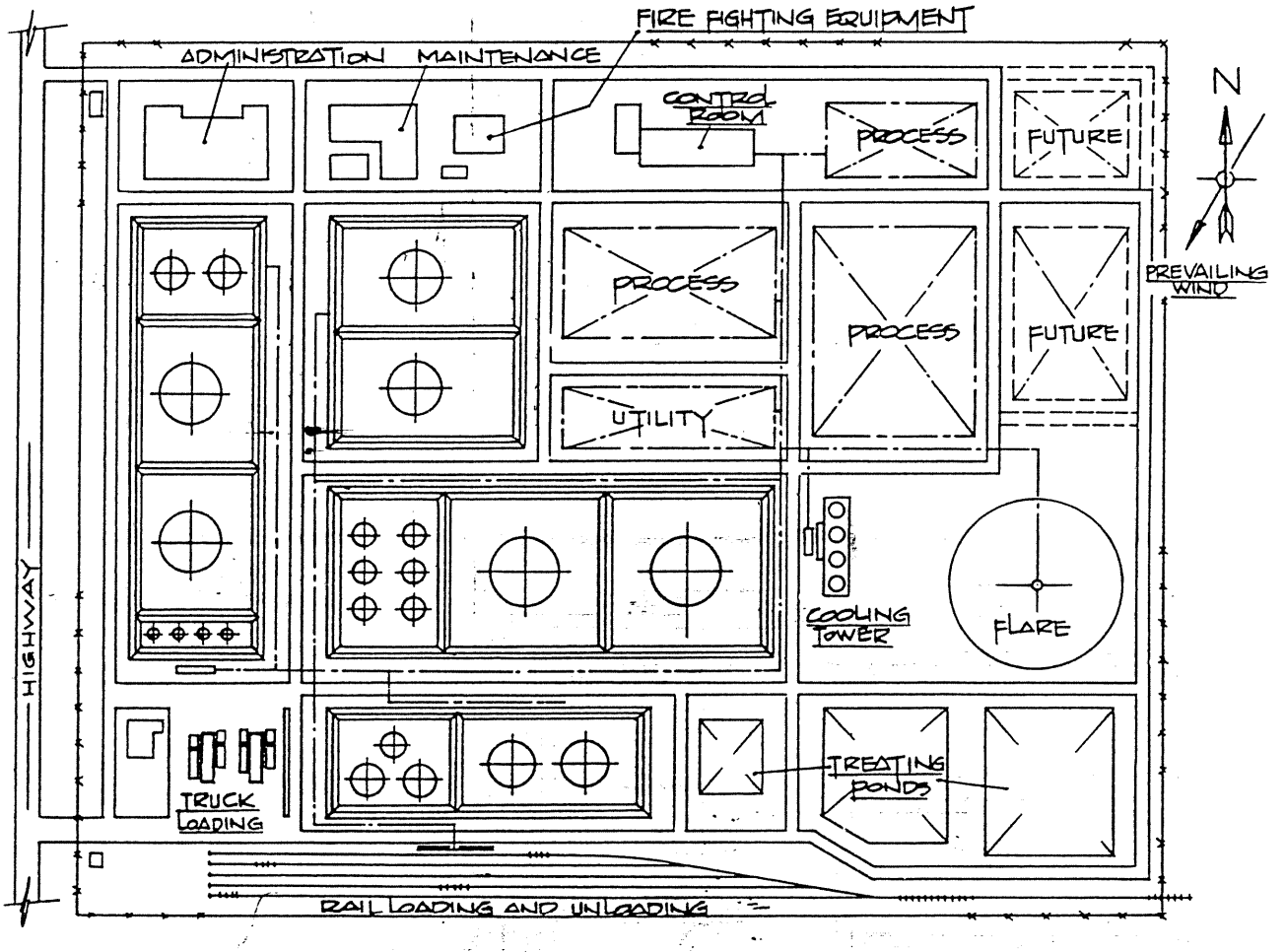


EXHIBIT 15-51
Tank Fire Water System

EXHIBIT 15-52 Overall Process and Off-Site Plot Plan



cess units and the utility plant are located in the central and eastern section of the plot, and allowances for future expansion are made. Storage tanks are located in the western and southern sections of the plot. Truck and rail loading and unloading areas are located together in the south and southwest corners of the plot. A flare stack, a cooling tower, and treating ponds are in the southeast corner.

Process units are located as far away as is practical from the storage tanks and product-loading areas. In cold climates, the wind will carry exhaust gases from the cooling tower, across the storage tanks, and away from busy process units.

Tank farms can occupy vast areas of valuable real estate within a process facility. Development of the optimum design, considering all applicable codes and regulations, is achieved only through close attention to safety and economics. Although many solutions to layout problems are possible, a mixture of proven methods—along with the commonsense lessons of trial and error—will produce the optimum design.